Engineers Year Book

1896

University of Minnesota

THE
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OF THE
SOCIETY OF ENGINEERS

The YEAR BOOK is a scientific publication issned by the Society of Engineers in the College of Engineering, Metallurgy and the Mechanic Arts in the University of Minnesota. It is essentially technical in its scope and contains articles contributed by active and honorary members of the society.

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1896

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PROFESSOR H. E. SMITH.

THE

YEAR BOOK

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MAY, 1896.

PROFESSOR SMITH.

Harry Ezra Smith was born January 16, 1865, in Pike, Wyoming County, New York. He was the only son in a family of five children, the ninth generation from Rev. Henry Smith, who was the first settled minister of Wethersfield, Connecticut, having come from England about 1636. His mother, Amanda Adams Smith, was a descendant of John Adams, who landed at Plymouth, Massachusetts, from "The good ship Fortune" in November, 1621. Although the father, who was a woolen manufacturer, died when the subject of this sketch was only fourteen years old, the mother managed to educate her children. After completing the course at Pike Seminary in his native town, the young man was appointed to a scholarship at Cornell University in 1882. Here he maintained an excellent record, taking the First Prize in Sibley College during his Junior year for "greatest merit in college work." He graduated from the Mechanical Engineering course in 1887, receiving honors for general excellence, and honorable mention for his graduating thesis on a "Trial of a Babcock and Wilcox Boiler."

While pursuing the technical course he was also wise in gaining practical experience by actual work in shops. An interval in his college course was spent in the employ of the Straight Line Engine Company, of Syracuse, N. Y. After graduation he followed this up by several months' experience with the Brown & Sharpe Manufacturing Company whose reputation is world wide for accurate and precise workmanship in standard gauges, tools, and fine machinery. After a thorough study of their shop methods of doing work and keeping records, he resigned to take a position as assistant foreman with the Woodbury Engine Company, of Rochester, N. Y. This position in turn was given

up in order to become an assistant in the erecting department of Wm. Sellers & Company, of Philadelphia.

In the spring of 1888 Mr. Smith had the good fortune to secure as a life companion Miss Minnie R. Ballard, of Centerville, Allegany County, N. Y.

In the fall of 1888 he was tendered an instructorship in Sibley College, Cornell University, which position was held for one year, when he was called to the University of Minnesota as Instructor in Woodworking and Foundry Practice. From this position he has risen step by step until, upon the resignation of Professor W. A. Pike in 1892, he was given full charge of the Department of Mechanical Engineering with the rank of Assistant Professor. Since the advent of his present associate, Assistant Professor Hibbard, Mr. Smith has been able to devote his attention more largely to his chosen specialty of Experimental Engineering.

Professor Smith's reputation for accurate work in experimental engineering has created frequent demand for his services in conducting efficiency and capacity tests of steam engines, boilers, and other mechanical products. These calls afford unexcelled opportunities for the advanced Mechanical and Electrical Engineering students to take part in the observations and calculations of commercial tests and to become familiar with some of the problems presented to engineers in active professional practice. Such extra-mural laboratory work is highly prized by the students as supplementing the working equipment of the University and enlarging the practical development of the Engineering courses. During the past year, the students have assisted Professor Smith in efficiency and capacity tests of three one hundred and twenty-five horse-power compound high-speed Ames engines, directly connected with electrical generators, a twelve hundred horse-power vertical triple expansion compound Schichau engine, and a sixty horse-power Ball engine, besides a number of minor tests.

Professor Smith keeps in close touch with educational and professional colleagues. He is a junior member of the American Society of Mechanical Engineers, and a member of the Society for the Promotion of Engineering Education. He was a charter member of the first chapter of the Society of Sigma Xi, founded at Cornell University in 1886, and is also a charter member of the chapter just established at the University of Minnesota.

GEO. D. SHEPARDSON.

MODERN FOUNDRY PRACTICE IN CONNECTION WITH MANUFACTURE.

JOHN MORRIS, '88.

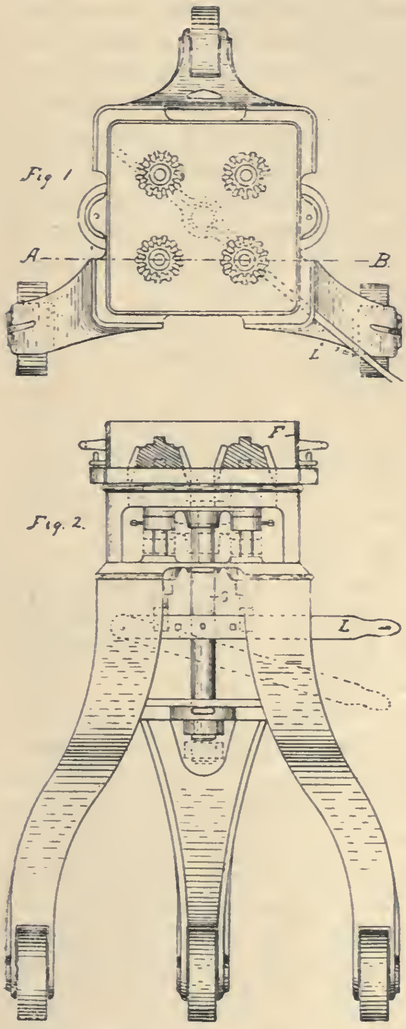
Though the working of metals was practiced by the ancients early in the history of civilization, the practice of founding was not very extensively carried on until within the last three centuries. We find a mention of working iron recorded in the Scriptures at an early period (Gen. 4:22). Whatever may have been unrecorded in the history of iron manufacture in the early ages, enough has been written to establish the importance of the iron industry throughout the civilized world since its early discovery.

The method of working iron, as well as the difference in product, varied in the early history from what we find in mediæval ages; and all this differed greatly from what we find to be the history of this important industry during the last few centuries. It is not our object, in this short article, to even attempt to give the early history of this widely diffused metal, only as much as is necessary to get at the growth of this industry during past ages, and thus assist in showing the rapid development during our own present century. It seems from good authority that the reduction of the iron ores has been practiced since quite a remote period in various countries, and that, too, with considerable success in producing iron and steel, at different periods in their history. A few uncertain mentions are made of cast-iron having been produced several centuries preceding the Christian era; also, a few scattering references are made to casts of various kinds produced during the early centuries of our present dispensation.

This is certain, though records are practically silent, that very little was done except the production of iron and steel from open hearths, until the eighteenth century, when the practice of founding became generally known. Much credit is due to the early promoters of the iron industry, but doubtless a greater advancement has been made in the manufacture, both

in kind and quality, of this most useful metal, during the last quarter of a century, than in all preceding time. While there has been a very great development in this line, possibly the greater advancement which has made this first possible, is due to the general improvement in the method of making castings and the introduction of moulding machines. Up to the last twenty-five years, nearly all the moulding was done by hand after the original method; and, indeed, much of the work is being done after this method in our modern foundries, and in many the work is still carried on exclusively after this method. The fact that it was the only method originally pursued, and that it is still extensively practiced in nearly all foundries, speaks well of this method in more than one way. While it has the advantage of being inexpensive when only a small number of castings are required, it always has the disadvantage of producing imperfect work. When a pattern of a desired casting is put in a flask, and the sand is properly "rammed" around it, the most important part of the task remains yet to be accomplished. The removing of a simple pattern from the sand mould is not attended with any great degree of difficulty, but with a complex piece the reverse is the case. The first operation is to "sponge" the pattern. This is done by following the outline of the pattern with a very small stream of water from a sponge. After this is done the pattern is rapped by either tapping the pattern itself, or placing an iron piece in a hole or socket in the pattern, which serves also as a lifter, and rapping this sufficiently to loosen the pattern in the sand. It will readily be seen that the rapping of the pattern produces most of the imperfection. For example, take an ordinary bevel pinion, which is moulded on end. This is rapped sideways, right and left, and possibly a little in a direction at right angles. It will be observed that the teeth, on the right and left sides, will be long by reason of the rapping sideways, while the teeth on the sides at right angles will appear thicker and not as long, a condition which renders a pinion entirely unfit for use. This is not always the case, as many patterns are but little affected by such a variation as this; and this variation depends largely on the care and skill of the moulder; but in general it will apply to all small patterns. The "carding" of patterns on small work eliminates this difficulty to a certain extent, while it also has another merit, of producing from six to a dozen pieces as cheaply as if only one pattern was used. The patterns are gated to-

gether, two, four, six, or a dozen, depending on the size of the pattern, with runners in between. A "sand match" is often used with a card, and this greatly facilitates the work. The card is taken and a "sand match" is made to fit the pattern up to the parting line. This enables the moulder to work rapidly and produce comparatively perfect castings. With large castings, the difficulty attendant upon small patterns is to a great extent removed and is supplemented by still other difficulties. The continual practice and experience in handling large castings has been a means of bringing about methods that now enable workmen to produce a great many difficult castings with comparative certainty.



The advantages of the moulding machines over the hand method are twofold; principally in producing better moulds and, consequently, better castings; and, subordinately, in reducing the cost of the work. The construction of moulding machines varies with the class of work and the kind of castings. Different manufacturers also make such machines as are best adapted to their individual need, but the general principle of the moulding machines is much the same. Briefly described, it is as follows: A moulding machine consists of an iron stand of suitable dimensions to accommodate the pattern or patterns, and of such height as is found convenient for an ordinary workman to manipulate and handle the flask.

Figure 1 shows the plan of an ordinary moulding machine, and Figure 2 is an elevation in section on line A—B. The patterns are raised into position, as shown in Figure 2, and held in place by means of the lever L, and the vertical standard S. The moulding sand is put into the flask F, and properly "rammed" in the usual way, and now the patterns are mechanically removed, by means of lever L, and are dropped down to the position showed in dotted lines; then the flask is taken up off of the dowel pins, inverted and examined, to see that all parts are perfect, and then is placed in position on the moulding floor. Figure 3 is a plan, and Figure 4 the elevation of the stand for the counterpart; and in this is only a "match plate". As is seen from construction, it is not necessary to have the patterns movable in Figures 3 and 4, though often the patterns are such that both parts must be made movable. The moulding sand is put into the flask and "rammed" as before, and now the flask F′ is taken up, examined, and then put into position on flask F. Generally the moulder runs ten or twenty-five flasks of the "drag", putting same in position on the floor, and now changes over and uses the machine for the "cope" shown in Figures 3 and 4, and making the mould for the counterpart and putting these into position on the drag flasks, and so on for the day's work. It is now obvious that the removing of the patterns from the sand, mechanically, does not require any rapping, and, consequently, leaves the mould as perfect as the pattern. Often patterns have only one or two projecting parts, while the rest of the surface is comparatively uniform, or at least has plenty of "draw", and the flask can be readily removed from the surface. In such a case the projecting parts only are made movable and the pattern is made on the top plate of the stand as a "match plate", and the projecting parts are made to fit closely when in place; and when the sand is properly "rammed" they are mechanically removed, and dropped down entirely out of the mould by means of a lever, practically as shown in Figure 2.

Fig. 3.

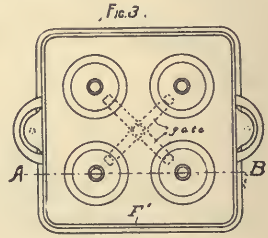
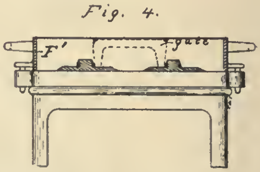


Fig. 4.



The carding of patterns on moulding machines may be and is practiced whenever the size of a pattern will admit. This,

of course, refers only to small patterns though castings of considerable size are successfully made on machines with the use of mechanical or pneumatic hoists. When large patterns and heavy flasks are used, the air hoists produce a very satisfactory result, and are being introduced wherever the amount and quality of work requires such an appliance.

Having now produced the moulds, either by hand or with a moulding machine, we are ready for the second important operation that the moulder has to perform, and that is pouring off the metal.

However, before proceeding with this part of the work, a brief outline of the work in the foundry will be here given, with a few formulæ of mixtures that are successfully used in practice.

The charging of the cupola requires close attention, and this varies with the class of work; and the success of this work depends largely on the good judgment of the foundryman in charge. The following will illustrate a method of charging in a 32-inch cupola:

On the bed 500 pounds of coke, and on this 2,000 pounds of iron; next, 100 pounds of coke, and on this 1,500 pounds of iron; continuing these amounts for the remainder of the charges. A cupola, charged like or similar to the above, will melt four to five tons per hour, and, if everything goes well, eight or ten tons may be melted in one heat, and even more has been accomplished under favorable circumstances.

In a cupola melting sixty-five tons daily, the following charges were used: Nine hundred or 1,000 pounds of coke on the bed, 3,000 pounds of iron; then 200 pounds of coke and 2,500 pounds of iron, and so on for ten charges, and the remainder of the charges, 200 pounds each of coke, with 2,000 pounds of iron.

A quantity of crushed limestone is thrown in with the charges during the process of melting for "flux".

For light miscellaneous castings, such as are used for agricultural machinery, the following formula will produce good results: Forty per cent. No. 1 soft pig; 30 per cent. No. 1 Bessemer; 30 per cent. good machine scrap, or, in lieu, No. 2 Bessemer.

There should be at least three kinds of iron, of different grades, in order to secure good results. For a heavier class of castings, the following is a good mixture: Forty per cent. No. 2 soft pig; 20 per cent. No. 1 Bessemer; 20 per cent. No. 2 Bessemer; 20 per cent. good scrap.

The quality of the soft irons has more to do with getting good results and suitable castings than that of the hard irons. A good casting should possess these conditions: Sound casting, free from blowholes and flaws; strength to resist strain; and soft enough to work well with a tool. Following will be given the mixtures A, B, C, recently used; and the result in each with three test bars taken from the beginning, middle, and end of heat. It will be noticed that the three mixtures are alike, only differing in proportion. It will also be noticed that the A mixture produced test bars that were low in transverse strength, and the same showed weak castings in the construction, while B and C showed well and produced good results.

A.

33⅓ per cent.	Bessemer		2200.
26⅔ "	scrap		2380.
23⅓ "	No. 2 Foundry		2220.
16⅔ "	soft		

B.

20 per cent.	Bessemer		2100.
33 "	scrap		2580.
27 "	No. 2 Foundry		2820.
20 "	soft		

C.

26 per cent.	Bessemer		2618.
28 "	scrap		2690.
26 "	No. 2 Foundry		2700.
20 "	soft		

The following mixture was made for especially high-grade casting and proved to be very good, giving a strong and sound casting, soft enough to work well. This would be very suitable for large engine cylinders and such classes of work:

25 per cent.	Imported Scotch Summerlee	Average strength, 2800 lbs.
50 "	Hanging Rock, charcoal (Ohio)	
15 "	Lake Superior	
10 "	good scrap	

Other mixtures now being used for light castings produce very satisfactory results in every way, of which is the following:

40 per cent.	No. 2 soft	Average strength, 2475 lbs.
15 "	No. 1 Bay View	
10 "	No. 2 Bay View	
33 "	scrap	
2 "	Ferro Silicon	

The chemical analysis of No. 1 Bay View is as follows:

Silicon,	2 to 2.50
Phosphorus,	.20
Manganese,	.32
Sulphur,	.023
Carbon,	3 to 3.25
Iron,	93.80

Having now mixed and melted the iron, it is ready for the last operation of pouring the metal into the moulds previously prepared. This is attended with some difficulty, and must be done with care to avoid washing away the wall of the mould, and the blowing and swelling of the casting. With large casting the transporting of metal and pouring off is done mechanically, by means of foundry cranes, and often large ladles weighing many tons are used and handled with success and safety.

The castings are allowed to remain in the sand until sufficiently cooled, and are then taken out, ready to be sent to the tumbling mills for cleaning, and the sand is sprinkled and shoveled over, ready for the next day's work.

FIRE-PROOF FLOORS IN MODERN BUILDINGS.

F. L. DOUGLAS, B. C. E., '91.

The remarkable and continually increasing use of the "steel skeleton" type of building construction since 1887 or 1888, at which time the advantages of iron and steel in building construction became generally recognized, has necessarily created a demand for a suitable material for the floors, ceilings and partitions of buildings, to serve the twofold purpose of protecting the expensive iron work from fire, and of safely sustaining the loads likely to be imposed.

In order to protect the iron work against fire this material must itself be thoroughly fire resisting. It must also cover the iron work to such a depth that in case of fire the iron will not be heated to a dangerous temperature. The common end in view in the discussion of fire-proof floors is to ascertain what system most nearly fulfills the conditions of efficiency, minimum cost of manufacture and erection, and maximum speed in erection.

Fire-proof floors may be divided into two general classes:

First, floors composed of separate pieces, generally brick or terra cotta, joined together along nearly vertical joints by cement or mortar.

Second, floors of a monolithic construction, made generally of concrete, in which iron may or may not be imbedded, to act in conjunction with the concrete in performing its work.

In the first general class the use of brick arches may be dealt with in a few words, since it is becoming more and more obsolete. The objections to brick arches are their great weight, limited strength, and difficulty of protecting the bottom flange of the supporting beam against fire.

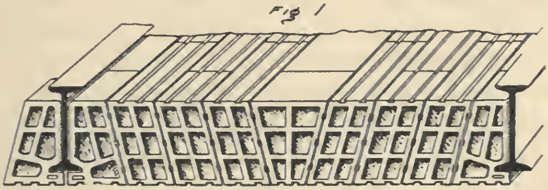
The weight of a brick arch, together with the concrete filling on top, is about 70 lbs., or varying from 20 lbs. to 35 lbs. greater than the hollow tile, and 40 lbs. greater than some of the lightest types of floor construction. This excess of weight requires heavier beams, girders and columns at a correspondingly greater cost. Tests have shown that when brick arches

are loaded eccentrically, as all floors are liable to be, they are surprisingly weak. The bottom flange of the beam or girder, supporting brick arches, is left exposed, since the lower part of the web and the top of the bottom flange form the skewback for the arches. Brick arches are poorly adapted to take ceilings. Brick arches when made of a good quality of red pressed brick have a very neat appearance from below and when this consideration is a prominent one they may be advantageously used.

HOLLOW TILE ARCHES.

Hollow tile seems to have been first used for floors in Europe. Mr. F. Von Empberger speaks of the Liverpool flags used in 1853 consisting of a single tube running from beam to beam, the spans being very short. Although taken up in the United States at a later date, we find this system of fire-proof flooring developed to a much higher state of perfection and far more extensively used than elsewhere. In Europe the single tube is still used and a liberal thickness of concrete is placed on top. This furnishes most of the strength to the combination, reducing the function of the tile practically to that of ceiling tile.

Fig 1

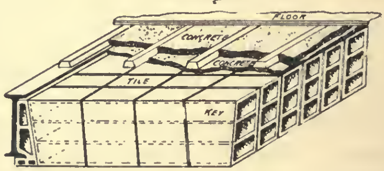


HOLLOW TILE FLAT ARCH
SIDE CONSTRUCTION

Not until the era of "skeleton construction" began, however, was hollow tile or any other form of fire-proofing extensively used. The number of different forms of hollow tile which have been used or proposed in the meantime is very large, but they may all be comprised at present under the following heads, viz.: Side construction (Fig. 1.) End construction (Fig. 2). The distinction between the two being that in the former the voids run parallel with the beams, and in the latter the voids are perpendicular to them. In both of these types all the ribs are straight. Many designs have appeared on the market in which the ribs were more or less curved in the endeavor to conform to the curve of equilibrium of a loaded arch. These forms may or may not have a flat ceiling. In the former case the inclined ribs are carried down below the arch ribs to the plane of the intended ceiling, supporting the

horizontal part of the block and thus forming a level ceiling. In the latter case the arrangement of the blocks is very similar to the ordinary brick or stone arch having a curved soffit. The floors having curved ribs meet more fully the engineering aim to distribute the material in the curve of equilibrium so as to produce the maximum efficiency. The great objection to curved ribs is that the blocks made for one span of arch are not adapted to other spans, and since, in buildings of any considerable size, a great number of different spans exist, an enormous number of different shapes are required, increasing the cost of manufacture and the difficulty and time required in getting the right block to the right place. A compromise between the various elements of the problem is effected by the use of the two types illustrated and referred to above. In these, comparatively few shapes are required; a small variation in span being provided for by using a key of different thickness and greater variations by using a greater or less number of Voussoir blocks. These types furnish a flat surface both above and below, a very desirable feature.

Fig 2



HOLLOW TILE FLAT ARCH
END CONSTRUCTON

In all hollow tile arches a layer of concrete is placed on top in which are imbedded nailing strips for the floor boards.

A large number of tests have been made on hollow tile arches, giving a very wide range of results.

A series of six tests of the strength of hollow tile arches of the side construction type, made at Trenton, N. J., in 1894, gave a breaking load of from 298 lbs. to 839 lbs. per square foot uniformly distributed. Tests were made on hollow tile segmental arches, span 15 ft. 4 in. One test made with load extending up to the middle of the arch, from one beam, gave a breaking load of 1,000 lbs. per sq. ft. over the loaded area, or 500 lbs. per sq. ft. over the entire area of the arch. The concrete filling in the haunches was green, otherwise the test would probably have been more satisfactory.

Another test of a similar arch, uniformly loaded, carried 1,200 lbs. per sq. ft. on the loaded area with only a slight permanent set, though it is certain that a portion of this load was carried by adjacent unloaded portions of the arch; hence the above figures should be considerably reduced for comparison.

A series of twenty-seven tests recently made by Geo. Hill, Mem. Am. Soc. of C. E., on hollow tile arches, led him to conclude, so far as this limited number of tests would indicate, that "side construction" arches were very weak in the skewback and that "end construction" arches, when properly imbedded in good concrete against the beams, were very much stronger. Mr. Hill claims that a properly designed skewback has carried 5,000 pounds per lineal foot without failure.

As a protection for the iron work against fire, hollow tile has proved itself to be very efficient. A fire occurred April 2nd, 1893, in the Temple Court building, New York City. The wood floors, window and door framing and contents of offices furnished the combustible material and the fire raged fiercely for hours unchecked. When it was finally put out, an examination showed the hollow tile itself not only to be intact, but the iron was in no way injured.

This type of floor can be rapidly erected and for this purpose 2 inch planks are supported on timbers hung from the beams. The top of the planking comes about 1 inch below the bottom of the I-beams and the arch blocks are laid upon the plank, beginning of course with the skewback and working towards the center from both directions. No great degree of skill is required nor is a high grade of mortar necessary. The work of erection, to secure good results, should be carefully superintended. This, like any other work, will suffer for want of proper execution.

Because of the short time required for the mortar to harden, the floor can be used soon after erection. The weight of hollow tile arches, together with the concrete filling, varies according to the depth of arch and concrete, from 35 lbs. to 50 or 55 lbs. per square ft.

Hollow tile floors are poorly adapted to cutting away for the passage of pipes, etc., and where the floor beams and girders come together on a skew, the blocks require trimming to a Level, affording opportunity for poor workmanship and uncertain results.

The majority of tests upon hollow tile arches show them to fail suddenly, without preliminary deflection. Cracks occasionally appear and give warning of weakness, before failure occurs.

Where the hollow tile flooring is used, the floor beams are "caped" into the girders supporting them so as to make all beams flush on the bottom. This involves an additional cost

to the beams of about $4.00 per ton over the cost of beams simply framed together.

It is likely that more attention will be shown in the future, than in the past, to the proper design and manufacture of hollow tile arches, resulting in greater strength and more definite knowledge of their properties.

The recent appearance in the field of competition of various types of floor which show much greater strength, more uniformity of results, and having in some cases less weight, will be a strong factor in bringing this about, and force the manufacturers of hollow tile, who have hitherto had little competition, to improve the strength and uniformity of their products.

CONCRETE IRON FLOORS IN GENERAL.

A book was published in London in 1877 by Thaddeus Hyatt, describing a building in which the combination of iron and concrete was used; also giving results of fifty tests. Mr. Hyatt refers to a still earlier publication, describing the use of the combination in France. Tests were made in America, as early as 1855, by R. G. Hatfield, of combination beams. In 1875 a dwelling was constructed in Port Chester, N. Y., in which Beton was used in combination with iron.

Whether or not the combination of iron and concrete for floors was first used in the United States is of less importance than the fact that in Europe it has attained an extensive commercial development not approached in this country. Its use in Europe developed in somewhat the same way, and under similar circumstances as hollow tile in this country.

The great advantage in the use of iron in combination with concrete is in securing a higher strength on the tensile side of combined concrete-iron beams than can be obtained with concrete alone.

Evidence is quite conclusive that concrete is remarkably well adapted to preserve iron, when the latter is imbedded completely in the former. A piece of iron was found to be in a perfect state of preservation, after being imbedded in concrete over 400 years. The modulus of elasticity of concrete, according to Prof. Boeck, is one-fortieth that of steel, enabling the steel to take a forty times greater load under the same strain or deformation. The cohesion between iron and concrete exceeds the strength of concrete itself. The thermic expansion of both is the same; therefore no secondary stresses occur when the temperature changes.

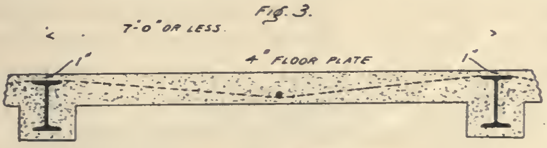
The time required for the setting of some types of concrete-iron arches before they are capable of sustaining a heavy load, is an undesirable quality, since a much larger quantity of centering is required, and often times arches are called upon to carry their heaviest loads very soon after completion, for the storage of materials.

Any floor system consisting of concrete and iron in combination, will show the effect of excessive loading or faulty construction generally by the appearance of cracks, or undue deflection, in time to remove the loading and prevent collapse of the floor, while with hollow tile construction failure is generally the first evidence of weakness. Concrete is not generally regarded as possessing as good fire-resisting qualities as hollow tile, yet many maintain that it will not disintegrate under a severe fire and water test. At a recent meeting of the American Society of Civil Engineers, the discussion which followed the reading of a paper on fire-proof floors showed a general belief that concrete was not as good as hollow tile in resisting fire and water.

Metropolitan System

The metropolitan system of fire-proof floors as such, has been on the market about two years. It consists, briefly, of

FIG. 3.



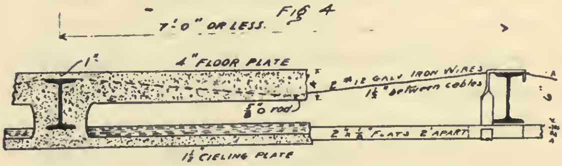
METROPOLITAN SYSTEM
WITHOUT CEILING

iron cables running continuously over the tops of the floor beams and imbedded in a "floor plate" usually four inches thick, made principally of plaster of paris and sawdust, the top of the plate being one inch above the top of the floor beams. When a flat ceiling is not required (Fig. 3), the wire cables consisting of two No. 12 gauge twisted galvanized iron wires are run continuously over the tops of the floor beams and secured by hooks to the last beams. The cables sag between the beams and a uniform deflection is given by laying a ⅝ in. iron rod on the wires, midway between the beams. A level "center" is next placed so that the top is 3 in. below the tops of the beams and the composition, as above described, is applied after being mixed together in the proportion of five to one by weight, with enough water to become plastic. The center extends down around the bottom part of the beam so that after the com-

position is in place the beams and wires are entirely imbedded.

In cases where a flat ceiling is required (Fig. 4), 2x⅛ in. iron flats placed on edge and running at right angles with the beams are suspended by hooks from the latter so as to come immediately under the bottom flanges, wire netting is secured to these bars and the composition is applied as above described, but is only about 1½ in. thick. The main floor plate which is about 4 in. thick and the covering for the beams are then applied. All iron is covered by at least one inch of the composition. The hollow space thus formed between the "ceiling plate" and the "floor plate" is convenient for laying pipes and wires, as well as for the non-conduction of heat and sound.

FIG 4



METROPOLITAN SYSTEM WITH CEILING.

It is claimed by the manufacturers that the composition will harden so as to be at once capable of sustaining, with safety, the load for which it was calculated. Plastering is applied directly to the composition and boards for the floor are nailed to strips imbedded in it.

Quite extensive tests have been made on this system, which show very satisfactory results. About six tests carried to partial or total failure, made by the manufacturers in the presence of a number of architects, showed the floor to have an ultimate capacity of from 1,300 lbs. to 1,900 lbs. per sq. ft.

This floor has also withstood severe drop, fire and water tests satisfactorily.

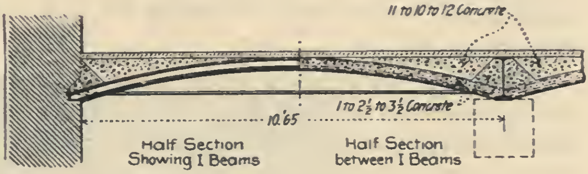
The weight of this system of flooring is, the writer believes, the lightest on the market, being, when thoroughly dried, only 28 lbs per sq. ft. of floor, exclusive of beams, plaster, ceiling and boarding. The cost varies from 16c to 24c per sq. ft. without a level ceiling, and 18c to 26c with a level ceiling. This system possesses better fire-proof than water-proof qualities. Heavy rains have occurred during erection which penetrated the top floors, dripping down upon the floors below with a portion of the plaster of paris in solution. The composition is very disagreeable to handle, it is said. The principal objection to the system, however, is the discoloration of the ceiling caused by the gradual working to the surface of the water used in the mixture after it has taken up the coloring

matter contained in the wood shavings and iron rust. The retention for a long time of moisture by the sawdust is also an undesirable feature.

Melan System.

This system was first used in Europe in 1893, principally for floors and vaults. Although the use of the Melan system in this country has thus far been confined to the construction of highway bridges, a brief description will not be out of place.

Fig. 5

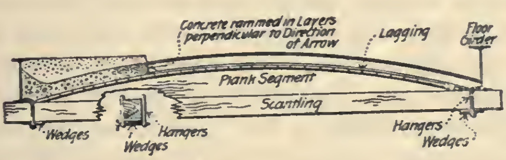


MELAN SYSTEM

This system consists ,briefly, of curved I-beams imbedded in concrete. (See Fig. 5.)

These curved beams abut against and rest upon the webs and lower flanges respectively of the girders, and are arched so that the top of the ribs are flush with the tops of the girders; the ribs are made to fit tight between the girders by the use of wedges driven between the webs of the ribs and girders. No riveted connections are required. After the ribs are in place a centering is provided with tight lagging (see Fig. 6), which conforms to the intrados of the arch. This centering is placed so as to come about one inch below the bottoms of the ribs, in order that the iron work may be entirely covered with concrete. The concrete is rammed in layers extending from rib to rib, beginning at the haunches and working toward the crown from both directions. This concrete, which must be of good quality, extends only to the top of the iron ribs. The space above is filled in with poorer concrete and cinders or other refractory material to form a level top and imbed the nailing strips which re

Fig. 6.



SHOWING METHOD OF CONSTRUCTING MELAN ARCHES

ceive the floor. The size and arrangement of I-beams and depth of concrete for various distances between girders is given in the accompanying table.

Space, feet with rise of 1-12 to 1-15.	I-Beams Depth, ins.	I-Beams Weight.	Dis. apart, ins.	Weight, lbs. per sq. ft. of floor.	Depth of concr. in ins.
10 to 12	3	6	40	1.8	4
12 to 16	4	6	40	1.8	4½
16 to 20	4	7½	40	2.25	4½
20 to 24	5	10	50	2.4	5½

The speed attained in laying according to an example given in the *Engineering News*, was two cubic feet per man per hour, or four to six square feet per man per hour. It is stated that this is a low speed record.

Tests show this system to possess very great strength. The relative strength of several systems of arches when of same thickness is stated by Mr. Von Empberger, who represents the Melan system in this country, to be as follows: Brick arch, 1; Concrete, 5; Manier, 16; Melan, 36.

The claim is made by some that the Melan system depends for efficiency upon too many elements. The time required for setting of the concrete before centers can be removed is at least one week.

Care is required to secure good mortar, thoroughly mixed and properly rammed into place, necessitating careful superintendence where common labor is employed. The ribs must be free from rust when erected, to secure a proper bond between the concrete and the iron. The system is not so well adapted to form a flat ceiling as some others. The concrete in this system is called upon to transmit stresses in two directions—a condition which should be avoided where possible in sound engineering—the concrete acts as a beam between the ribs and also as an arch between the girders. The Melan system seems better adapted to use in warehouses, etc., where great strength is required, than in office buildings and others subjected to a moderate loading.

Roebling System.

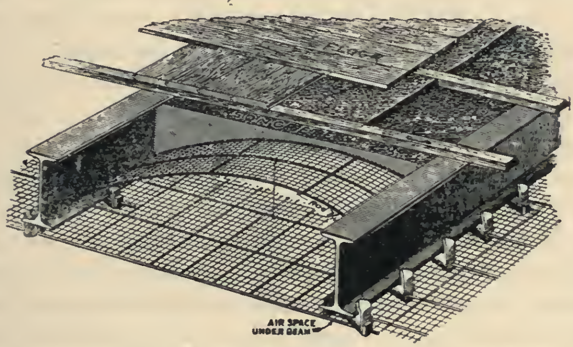
This system is identical in the main with the Manier system of Europe.

The system as adapted to floors consists of a "wire cloth arch, stiffened by steel rods which are sprung between the floor

beams and abut against the seat formed by the web and lower flange of the I-beams." On this wire arch Portland cement concrete is deposited and allowed to harden. The concrete is filled in so as to form a level surface on top, to receive the nailing strips and floor boards. A level ceiling is provided, as shown in the illustration, by running a system of iron rods from beam to beam and attached to them by means of patent clamps.

The ceiling, which is suspended below the bottom of the floor beams by means of the patent clamps, allows free circulation of air under the beams after the plastering is finished, a feature upon which considerable stress is laid by the manufacturers. The advantage claimed is that, in case of fire in a particular spot, the air, being free to circulate, is not apt to become so heated as to injure the iron, while, if confined to a small space, it is liable to become highly heated and communicate the same temperature to the iron beams. The continuous air space is a feature possessed by no other system.

FIG. 7



ROEBLING SYSTEM

The cinder concrete which is generally used, is combined with sand and cement in variable proportions. At a building visited by the writer the proportion was one part Portland cement, two parts sand, and five parts cinders.

When extra heavy loads are to be provided for, as in warehouses, broken stone is used in place of cinders, increasing the strength as well as the weight.

The results of tests given in the manufacturer's pamphlet upon floors in buildings show the arches to sustain from 1,000 to 1,200 lbs. and in one case 2,490 lbs. per square foot, without sign of weakness in the former and without failure in the latter.

As to the ability of concrete to withstand fire and water, there seems to be a difference of opinion.

The writer tested a piece of concrete used in this system, taken from the floor of a building about two minutes before

the test, and after heating it to almost a white heat immersed it in cold water. The cinders were unaffected, but a considerable portion of the sand and cement separated from the mass, leaving the latter considerably weakened. Others, who have made the fire and water test and who would have preferred poor results, say that it stood the test well.

The floors are used two days after being made and are guaranteed to withstand a test after being ten days old. Rapid progress can be made in laying this floor. The wire cloth is cut to the proper length at the mills, is quickly put in place, serving the purpose of a center, and the concrete can at once be put on.

The weight of the floor, as given in the pamphlet, varies from 47 to 59 lbs. per sq. ft., exclusive of iron beams. The cost varies from 18 to 23 cts. per sq. ft.

In the Roebling system the distribution of the material to withstand stress is such as to quite fully satisfy the engineering aim. The concrete being laid in the form of an arch, is subjected to little or no tension. If tension is developed in any part of the arch it will be at the intrados, where the wire cloth is placed to resist it. The wire cloth, having considerable strength itself, will protect any weak spot due to possible defective laying of concrete. Care must be exercised in laying the wire cloth, that the crown does not come too high, in which case the concrete at the crown, where it should be about 2½ in., will be too thin and thus impair the strength of the arch.

This system is well suited to cutting away for pipes, etc., and the hollow space is convenient for laying them.

Columbian System.

This system was invented in this country and has been in use about three years, during which time 27 different buildings or groups of buildings have been supplied with it.

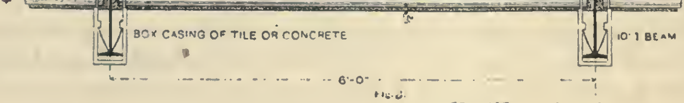


FIG. 8.

COLUMBIAN SYSTEM

The Columbian system (see Fig. 8) consists of bars of steel, shaped so as to give a large area, for the concrete to adhere to. These bars rest in "U" shaped stirrups which lie on the top of the I-beams. The bars and stirrups are imbedded in the

middle of a concrete slab, in much the same way that the wires are imbedded in the composition in the Manhattan system.

Accounts of tests given in the catalogue, show very satisfactory results. One floor sustained 1,154 lbs. per sq. ft. without deflection. A remarkably severe fire test was made upon this system in Pittsburg in 1895, under conditions specified by the Board of Fire Underwriters of Allegheny County, Pa. A section of floor in an enclosed space was subjected to intense heat for an hour and then drenched with water. During the test the arch carried a load of 750 lbs. per sq. ft. It is stated that the arch was uninjured.

Like concrete in any other form, it requires some time to set before it is safe to use—probably two or three days, depending on circumstances. The weight of this system, as given in the catalogue, is from 30 to 50 lbs. per sq. ft. The cost varies from 15 to 25 cts. per sq. ft.

The Columbian system is open to one objection from which many others are free, viz.: The steel used is of a special shape made by one concern, and a delay for any cause in obtaining the steel would necessarily delay the progress of the work; while a floor made of material which can be procured in the open market is less liable to interruption.

The advantage of combining iron and concrete, as has been stated, is to place the iron so as to strengthen the concrete against tension, and to do this, the iron must be near the soffit of the arch or bottom of the beam, where the tension exists. This is accomplished in a greater or less degree in the Roebling, Metropolitan, and Melan systems, but is evidently not aimed at in the Columbian, since the bar of steel is in the middle of the concrete slab.

Two other systems may be briefly mentioned in conclusion, namely, the Ransome system, and the St. Louis Iron Wire and Expanded Metal Company's system. Neither have thus far been used in the East. The former has been used in San Francisco, and consists of twisted square iron bars, imbedded in concrete near the bottom. The rods cross at right angles from side to side of the room at varying intervals, affording a good opportunity for making a very ornamental beamed ceiling.

The latter is much like the Melan system, with the addition of expanded metal, which is imbedded in the concrete over the entire surface of the floor, insuring the integrity of the latter. Channels are used for ribs in place of the I-beams of the Melan

system. These are placed with the trough up, which is filled with concrete up to the level of the girders. The expanded metal is then laid on and imbedded in concrete.

No system possesses all of the desirable features of a fireproof floor, nor all of the objectionable ones, but each combines them in varying proportions. The choice of a system depends upon so many conditions, some of which vary from day to day and others with the locality, that each case must be investigated for itself in determining the system best adapted to it.

IRRIGATION ENGINEERING IN THE UNITED STATES.

C. H. KENDALL, C. E.

The practice of irrigation has come to be one of the most important questions of the day. Its development on a scientific and practical basis in this country has been so rapid that Irrigation Engineering is now a recognized profession, and, at the present time, no branch of Civil Engineering is receiving more marked attention throughout the Western states.

Previous to 1882, no irrigation work was designed or constructed on sound engineering principles, but the development of this art has been so progressive in the past few years that now our works, while not of such magnitude as the English works in India, surpass those of Egypt, France, Spain, Italy, Mexico, and South America, which countries have irrigated for centuries, and do compare very favorably with those of India.

To illustrate the phenomenal growth of this new profession in the United States, mention may be made of the following: the flourishing American Society of Irrigation Engineers, organized in 1891; the transactions of the four National Irrigation Congresses; the numerous Irrigation Commissions and Conventions held annually; that California, Colorado, and Wyoming have their State Irrigation Engineers; that many of the Agricultural Experiment Stations of the State Universities have irrigation engineers enrolled on their staffs; and that now several periodicals are published devoted to the interests of irrigation.

This recent rapid growth is due to the recognition by the Federal Government of the importance of the subject to the future growth and prosperity of its people. Hundreds of thousands of dollars have been appropriated for furthering investigations on a scientific basis. In connection with the United States Geological Survey, hydrographical and hydrological surveys and investigations have been made that are of incalculable value. It is the official reports of these surveys, together with the investigations of the Department of Agriculture and of individ-

ual states, that afford us the best literature upon the subject.

The magnitude and intricacy of the problems met with require the highest degree of engineering ability, and the Irrigation Engineer, in order to cope successfully with these problems, must be especially well qualified in the principles of Hydraulics, Meteorology, Hydrology, Geology, Topographical and Hydrographical surveying, and Water Rights Legislation. The field is a large one, and though much has been done, the amount is but a small proportion of what will be done in the future. This is at once apparent when we remember that the population of the United States doubles every thirty years; that the center of population is steadily moving westward at the rate of fifty miles every ten years; and that now there is less than four million acres of land irrigated, while there still remains about three hundred million acres of irrigable land awaiting development.

We will now discuss, in a general way, as far as the present limits of this paper will allow, the present practice and methods employed in the West, taking up the following subjects:—

I. Division of territory.
II. Quantity of water needed.
III. Source of supply.
IV. Classes of works.
V. Distribution of water.
VI. Application of water.
VII. Economical and financial aspects.

Division of Territory.

As a matter of convenience, the United States has been divided into sections according to the amount of annual precipitation. These divisions are termed the "arid," "humid," and "semi-humid" regions. Where the rainfall is more than twenty inches, it is classed as a humid region; and here irrigation is not absolutely necessary, but very often so increases the yield and insures against crop failure that it becomes a very profitable consideration. In this region we may class the states and portions of states east of the 97th meridian, and also the western parts of northern California, Oregon, and Washington.

The region where the rainfall is from 12 to 20 inches is termed the semi-humid, and to this class belong the states of North and South Dakota, Nebraska, Kansas, most of Texas,

and Oklahoma Territory. Here some years rainfall is abundant, the crops luxuriant, and prosperity evident; then come dry years and failure of crops, which lead to discouragement, if not actual starvation. It is in this region of variable and uncertain rainfall that irrigation should be more studied and practiced; then certainty of crops would result, with a corresponding increase in yield, and not, as now, be a mere matter of speculation depending upon nature watering the land.

The states and territories west of the above region, having a rate of rainfall below twelve inches, belong to the arid region and no attempt is here made to cultivate the land without irrigation. We find here our most advanced irrigation works in operation; giving abundant crops every year and, where climatic conditions favor, often two or more crops are produced a year. The area of this section is about nine hundred million acres, much of which will never produce crops, even with water, because the climate and soil are unfavorable.

Quantity of Water Needed.

The term "duty of water" is used to express the amount of land a given quantity of water will irrigate. This duty is by no means constant, but varies throughout the arid region according to the character of the water supply, the methods of employing it, the character of the soil and crops, and the skill and experience of the irrigator.

The average duty of water is one hundred acres to the second-foot. Besides this generally accepted term for the duty, one meets with the following expressions in different localities: "Acre-inches," "acre-feet," "California miner's inches," and "Colorado miner's inches." One cubic foot of water per second is equal to: 86,400 cubic feet per day, 646,317 gallons per day, 2,700 tons per day, 24 acre-inches per day, 50 California miner's inches, 38.4 Colorado miner's inches. It will flood one hundred acres in one hundred days, twenty-four inches deep, or one hundred and fifty acres in one hundred days, eighteen inches deep, and so on.

The amount of rainfall necessary for raising a successful crop is about sixteen inches. In Utah, the average duty is one hundred acres per second-foot, and the following table, published by Professor Fortier, shows the various depths of water applied to the land in producing the crops mentioned,—calculated on the basis of one hundred days:

Crop.	Depth of Water.	Duty in acres per sec.-ft.
Strawberries......	27.50 inches	93
Cauliflower...........................	8.25 "	291
Tomatoes.............................	24.75 "	97
Mixed crop...........................	23.00 "	103
Barley......................	7.25 "	330
Corn....................................	3.75 "	660
Potatoes..................	16.63 "	143
Onions..................................	35.50 "	67
Peach Orchard......................	12 00 "	213
MEAN...............	16.40 "	256

SOURCES OF SUPPLY.

The climate, geology, and topography are the chief factors in determining the sources of supply, which we may class under the following heads: Rainfall; Running Streams and Springs; Storage Reservoirs; Ground Water, or Sub-surface Supplies; Artesian Wells; Ordinary Wells.

So far, all attempts to produce rainfall artificially have been unsuccessful. The first five sources furnish water for "gravity irrigation," which supplies ninety-nine one-hundredths of the irrigated land. The supply from wells is termed "lift irrigation," and though this method is almost inappreciable in extent, it is becoming more and more popular, due to modern improvements and special designs of pumping plants for the purpose.

CLASSES OF WORKS.

Herbert M. Wilson, C. E., in his work on "American Irrigation Engineering," includes five great classes of works in gravity irrigation, viz.: Perennial Works; Periodical Works; Storage Works; Irrigation from Sub-surface Sources; Irrigation from Artesian Wells. By perennial works are meant those canals which receive their supply from streams of sufficient discharge to afford irrigation at all times to the lands commanded by them. Among works of this class, the following may be mentioned as of particular interest and magnificence:—

(a) The Turlock Canal, diverted from the Tuolumne River in California. It has a total length of 180 miles and commands 176,110 acres. It has a capacity of 1,500 second-feet and the estimated cost was about $1,110,000.

(b) The Idaho Mining and Irrigation Company's canal, diverted from the Boise River, is 70 miles long and irrigates 350,000 acres.

(c) The Pescos Canal System, diverted from the Pescos River in New Mexico, commands, with several hundred miles of laterals, about 400,000 acres.

(d) The Bear River canal, from the Bear River in Utah, has 150 miles of main line and commands 236,000 acres. Its estimated total cost was $3,000,000.

Periodical works are canals taking their supply from streams which furnish water for a portion of the irrigation season only. Such works may be found supplying a limited territory throughout the West where the conditions are such that they supplement the natural supply in the soil which alone is almost sufficient for the cultivation of crops.

Storage works are constructed in intermittent streams, impounding the flood waters to supplement the flow, so as to insure a constant supply during the irrigation season regardless of rainfall.

There are various classes of these works according to character and location of the storage basins and sites of the dams. Among the most important may be mentioned:—

The Carayamaca earthern dam, in California, impounding 11,500 acre-feet of water and covering an area of 1000 acres. It is 635 feet long and 40 feet high. The water is conducted from it through a wooden flume 36 miles long, which passes over some 315 trestles.

The Bear Valley Reservoir, of California, has surface area of 2,252 acres and capacity of 40,550 acre-feet (10,000,000,000 cu. ft.). The dam is of ashlar masonry, 300 feet in length on crest, 64 feet high, and arched up stream with a radius of 335 feet. The new dam, located just below, is 120 feet high and also of curved form.

The Sweetwater Reservoir Dam, of San Diego, is of rubble masonry, 94 feet high, 380 feet long, and impounds 18,000 acre-feet (770,000,000 cu. ft.).

The Buchanan Reservoir dam is of uncoursed rubble masonry, 780 feet long, 100 feet high, curved with radius at centre of 1,146 feet. It impounds 42,400 acre-feet over an area of 1000 acres.

Irrigation from ground water sources is by tunnels under stream beds, or into the hillside to tap some water bearing stratum, or by open cuts in the sloping ground, or by wells to collect the ground water. These supplies are situated at various depths and large volumes of water are obtained from these

sources in various portions of the West. In California, submerged dams have been built across dry stream beds to cut off the under-flow and bring it to the surface. A great deal of water has been "mined" in both Colorado and California by constructing sub-surface canals or tunnels into the underground storage. Also a few depressed canals have been excavated along slopes.

Only a small amount of water used for irrigation is obtained from artesian wells. Still there are about 9,000 wells widely distributed, but mostly in California, Colorado, Utah, the Dakotas, and Texas. Artesian water is not as suitable for irrigation as surface and sub-surface water and is mostly employed for stock, small gardens, fruit trees, and grass. The cost is more than twice that of the ordinary method of obtaining water.

Water supplied by "lift" irrigation is one of the most promising methods of the future. Though relatively small in amount when compared with that from streams, it has great importance from the fact that dependence must be placed upon it in many localities where running water cannot be had.

Wind-mills have been extensively used and in connection with a small reservoir furnish a constant supply to a small acreage. Where good supplies are to be found, it is the cheapest way. Steam pumps are not yet fully appreciated, but pumping plants are coming into use and a large number are now in operation in all portions of the West; in California, Colorado, Wyoming, and Arizona in particular. Each pump supplies water for from fifty to one hundred acres. The use of the gasoline engine is finding favor, as it does not require constant attention, but will work automatically for several hours, or all day after once started.

Distribution of Water.

Methods of carrying water to the points of application are:

1. By canals or ditches, with or without masonry lining. The unlined is the cheapest, but much washing of banks occurs and the loss by percolation and evaporation is very large. When lined, they give excellent satisfaction, but are more costly than timber flumes.

2. Wooden flumes have been quite extensively employed in some sections and have been found to be the most economical when well made.

3. Concrete or stoneware pipe laid on regular grade gives

the least loss from evaporation, but the cost for maintenance is sometimes high, as the pipe is liable to be disarranged or choked by roots.

4. Wrought iron or steel riveted pipes, coated with asphaltum, to prevent rusting, are coming into use and have the advantage of wood or stoneware as regards evaporation. These can be used under pressure and consequently can be run in a direct line to the land to be irrigated. They cost more than wood and deteriorate rapidly in certain soils, but sometimes the length of line saved more than compensates for extra cost.

Application of Water.

The water is usually delivered, and where possible, at the highest point of lot, so it will gravitate to any desired point.

One method of irrigating, where water is plentiful, is to run the water in unlined open ditches and flood the entire surface. It is very wasteful and requires level land. When water is not so abundant, ditches are lined and the water is turned into basins about the trees or furrows about the crops and allowed to soak down into the soil.

On uneven ground it is necessary to use small iron pipes or timber flumes. The flow of the water is regulated by mechanically devised troughs and weirs.

Sub-surface irrigation is practiced to some extent and consists of a series of concrete pipes laid in the ground deep enough to escape disturbance by cultivation. This method avoids surface evaporation, but is costly and the pipes get choked by roots.

Economical and Financial Aspects.

The average annual cost of applying water, per acre, is from $0.75 to $2. However, in Southern California, $10 is not uncommonly paid where land is valued at $1,000 per acre for horticultural purposes. The average first cost of water supply is at the rate of $8.15 and its average value is $26 per acre. The following table taken from the United States Census Report for 1890, as prepared by F. H. Newell, of the Geological Survey, is very valuable as showing the extent and cost of irrigation and furnishing accurate statistics on the subject.

Extent and Cost of Irrigation.

States and Territories employing irrigation.	Crop irrigated.	Per cent. of area of irrigated crops to total land area.	Total number of farms with irrigated crops.	Per cent of area of irrigated crops to whole area owned by irrigators.	Average size of irrigated crops per farm.	Average first cost of water per acre.	Average value of water per acre as estimated by irrigators.	Average annual cost of water per acre.	Average cost of preparing land for cultivation per acre.	Average value of land irrigated per acre.	Average value of products from irrigated land per acre.
	Acres.				Acres.						
Total United States	3,564,416	0·50	52,584	20·72	67	$8.15	$26.00	$0.99	$12.12	$83.28	$14.89
Arizona	65,821	0·09	1,075	43·21	61	7.07	12.58	1.55	8.60	48.68	13.92
California	....	1·01	13,732	17·86	73	15.84	52.28	1.60	22.27	150.00	19.00
Colorado	....	1·34	9,659	31·09	92	7.15	28.46	.79	9.72	67.02	13.12
Idaho	218,249	0·40	4,333	26·08	53	4.74	13.18	.80	9.31	46.50	12.93
Montana	350,583	0·38	3,706	23·05	95	4.63	15.04	.95	8. 9	49.40	12.96
Nevada	224,403	0·32	1,167	14·13	192	7.58	24.60	.84	10.57	41.00	12.92
New Mexico	91,746	0·11	3,085	17·98	30	5.58	18.30	1.54	11.71	50.98	12.80
Oregon	177,944	0·29	3,150	15·89	56	4.64	15.48	.94	12.59	57.00	13.90
Utah	263,473	0·50	9,724	22·02	27	10.55	16.84	.91	14.85	84.25	18.03
Washington	49,399	0·12	1,050	17·21	47	4.03	13.15	.75	10.27	50.00	17.09
Wyoming	229,676	0·37	1,917	15·24	119	3.62	8.69	.44	8.23	31.40	8.25
Total for eastern sub-humid region	67,295	0·02	1,557	6·43	43	4.07	14.81	1.21	4.62	....	....
North Dakota	445	0·001	7	34·76	63	....	....	.25	6.42	....	....
South Dakota	15,717	0·03	189	29·95	83	3.20	17.90	.66	7.81	....	....
Nebraska	11,744	0·02	214	14·44	55	4.42	7.59	.48	4.86	....	....
Kansas	20,818	0·04	519	12·92	40	4.00	21.12	1.45	3.05	....	....
Texas	18,571	0·01	628	2·47	30	6.14	23.57	1.10	11.60	....	....

SOME EXPERIMENTS WITH BROM-CYAN.

H. C. CUTLER, B. E. M., '94.

Some few months ago the metallurgical world was stirred by the announcement of a new solvent for gold and, consequently, of a new process for its extraction from ores. The new solvent was a mixture of potassium cyanide and brom-cyan. Brom-cyan is a compound of bromine and cyanogen, having the formula of BrCN. A one-half per cent. solution of potassium cyanide and a one-quarter per cent. solution of brom-cyan will dissolve gold leaf nearly as quickly as aqua regia.

The writer has made a large number of experiments in the laboratory and on a working scale with the solution. On some classes of ores very favorable results were obtained, while on others the solution worked no better than the potassium cyanide alone.

The chemist who claimed the discovery of the new solvent used in his experiments crystals of pure brom-cyan, which he stated could be manufactured cheaply. At the time of making these experiments, the crystals of pure brom-cyan were not obtainable, hence a solution made by mixing bromine and a solution of potassium cyanide was used. In making this solution a number of interesting facts were noticed.

Two methods were used. In the first, a saturated solution of potassium cyanide and pure bromine were mixed. In the second, a weak solution of potassium cyanide (not over 5 per cent.) was added to water saturated with bromine.

In the first method, there was a violent action when the two chemicals were mixed and a large number of reactions took place. Potassium bromide (K Br) and caustic potash (K O H) were formed. The cyanogen radical (C N) was split up. The

carbon and nitrogen thus formed, uniting with the oxygen and hydrogen of the water, formed a number of organic compounds. Some of these organic compounds were thrown down in the state of a heavy black precipitate. The remainder were soluble and imparted a deep brown color to the resulting solution. The precipitate varied in amount each time the solution was made. Just what conditions are necessary for the least amount was not ascertained.

In the second method, the results were different. The violent action seen in the first method was entirely absent. Upon adding the solution of bromide in water to the weak potassium cyanide solution the resulting liquid remained perfectly clear until the bromide was in excess, when it assumed the light brown color of bromine.

The formula for this reaction was determined by the writer in the following manner: The strength of a saturated solution of bromine in water was found, by titrating with silver nitrate, to be 1.245 per cent. A burrette was then quickly filled with this solution. Ten cubic centimeters of a .3 per cent solution of potassium cyanide was placed in a small flask. The flask was then closed with a rubber cork in which there was a hole just large enough for the end of the burrette. The cyanide solution was then titrated with the bromine water. It took 2.95+ cubic centimeters of the bromine solution to neutralize the 10 cubic centimeters of the potassium cyanide solution. From the molecular weights it will be found that there was just enough bromine in the 2.95+ cubic centimeters of solution to unite with the cyanogen of the potassium cyanide to form brom-cyan (BrCN). Caustic potash (KOH) and no potassium bromide (KBr) was found in the resulting solution. The reaction, therefore, may be as follows:

$$2KCN + 2Br + O + H_2O = 2BrCN + 2KOH.$$

Greater economy would result in making brom-cyan by the second method.

These methods were used only for the purpose of experiment. If the process was to be used on a practical scale the crystals of brom-cyan should be obtained. The solution could then be made and handled much more conveniently.

The following table contains results of some experiments with potassium cyanide alone, and a mixture of potassium cyanide, and brom-cyan:

TABLE OF EXPERIMENTS.

Number.	CHARACTERISTICS OF THE ORE	Kind and per cent. solution used.	Time of Treatment.	Origin'l Assay. Ounces Ag.	Origin'l Assay. Ounces Au.	Per Cent. Extrat'd Ag.	Per Cent. Extrat'd Au.	Str'ngth of KCN after treatment.	REMARKS
1.	Concentrates. Heavy iron	a. 1. .5 KCN	20 hrs.	38.5	1.9	1.2	14.2	.32	100 c. c. of solution used
	sulphide partially oxidized	a. 2. "	40 "	38.5	1.9	4.5	18.7	.28	and about 50 grams of
	from being exposed,	a. 3. "	60 "	38.5	1.9	6.6	21.3	.23	ore alkali wash.
		b. 1. .5 KCN+.25 BrCN	20 "	38.5	1.9	13.4	47.6	.31	60 c.c. of KCN solution and
		b. 2. "	40 "	38.5	1.9	19.6	74.8	.28	50 c. c. of BrCN solution
		b. 3. "	60 "	38.5	1.9	26.3	92.5	.27	and about 50 grams of ore. Alkali wash.
2.	From pyrites panned out of	a. .3 KCN	72 "	2.3	2.28	78.3	86.85	.125	250 c.c. KCN used in a and
	ore after being treated by cy-	b. .45 KCN+.2 BrCN	72 "	2.3	2.28	81.8	87.72	.139	100 c.c. of each in b. About
	anide process for 48 hours.	.45 KCN+.2 BrCN	48 "	2.0	0.64	15.9	62.5	.0325	100 grams of ore. Alkali wash.
3.	Heavy iron pyrites direct	KCN		2.0	0.64	Little or no Extr'ct'n			
	from mine	a. 1. .45 KCN	60 "	2.2	0.68	9.1	11.7	.025	100 c.c. of solution and 50
		a. 2. "	40 "	2.2	0.68	2.3	9.67	.065	grams of ore.
4.	Same ore as No. 3 partially	a. 3. "	20 "	2.2	0.68	0.21	6.00	.08	[treatment.
	wasted	a. 4. "	20 "	2.2	0.68	9.09	17.6	.39	Water wash previous to
		b. 5. .45 KCN+.2 BrCN	60 "	2.2	0.68	18.1	12.1	.02	50 c. c. of each solution
		b. 6. "	40 "	2.2	0.68	4.3	9.86	.038	and 50 grams of ore.
		b. 7. "	20 "	2.2	0.68	0.2	8.75	.072	
		b. 8. "	20 "	2.2	0.68	10.	18.94	.343	Water wash.
		c. 9. .45 KCN+1 gram		2.2	0.68	13.6	9.67	.15	100 c.c. solution and about
		sodium dioxide	60 "	2.2	0.68	4.2	5.88	.175	50 grams of ore.
		c. 10. "	40 "	2.2	0.68	1.3	2.13	.192	
		c. 11. "	20 "	2.2	0.68	1.4	17.7	.35	Water wash.
5.	Silious ore containing 13.2	c. 12. "	20 "	2.2	0.68				
	per cent of iron pyrities	a. .5 KCN	48 "	14.24	4.72	27.2	48.3	.325	
		b. 1. .3 KCN+.25 BrCN.	24 "	14.24	4.72	56.7	73.4	.27	Alkali wash previous to treatment.
		b. 1. "	48 "	14.24	4.72	71.4	87.3	.243	

It will be noticed in the foregoing table that the loss of brom-cyan ($BrCN$) in treatment is not given. This is due to the fact that no satisfactory method of determining this loss could be devised. The potassium bromide (KBr) formed in dissolving the gold according to equation,

$$BrCN + 3KCN + 2Au = 2(KAuCN_2) + KBr,$$

interfered in the titration of the $BrCN$.

The experiments show that in some cases brom-cyan solution gives better results than simple potassium cyanide.

As the apparatus which was available for making brom-cyan on a large scale was very crude, the results obtained were not as satisfactory as the laboratory tests. There is no doubt that, if the brom-cyan solution could have been applied in the proper way, laboratory results could have been duplicated on a working scale.

NOTES ON MACHINE DESIGNING.

BY JOHN H. BARR, '83.

Assistant Professor of Machine Design, Sibley College, Cornell University.

The steam engine, like all other engineering constructions, is strictly subject to the laws of mechanics; but the operation of the engine presents such a complex problem in dynamics that it is practically impossible to base its design on purely rational methods. The varying steam pressure upon the piston is but one element in the complicated system of forces acting, as acceleration (linear and angular), friction, variation of the external load, gravity, etc., etc., all exert an influence upon the stresses produced in the members. These alone make the exact computation of dimensions for strength and rigidity exceedingly difficult; and, moreover, other considerations, both "theoretical" and "practical", are of equal importance, and must receive proper attention from the practical designer. He has to deal with the pressures upon the bearing surfaces and their velocities of rubbing, which affect the mechanical efficiency, durability, and freedom from heating. In many cases, the stopping of the engine during working hours is a more serious source of loss than is extravagance in the use of fuel. Thus, while thermal efficiency is of the highest importance, generally, it is only one factor in the final efficiency.

Apart from the engineering elements in the problem, there is always the commercial element. This requires the general use of regular standard forms and sizes when feasible, and often modifies the computations based upon pure mechanics. Economy of construction dictates the adoption of forms and dimensions which can be readily, accurately, and certainly produced in the shops. The limitations of the mechanic arts, as practiced in the foundry and machine shop, must ever be in the mind of the designer. As between the ideal form which can be produced only at great expense, and the "good enough" form which is a great deal cheaper, the latter is frequently the only one practicable.

Then again, a builder often has calls for engines which do not differ greatly in capacity, and he meets this demand by building two engines having the same stroke but somewhat different diameters of piston; for example, one is 11 x 12 inches and the other is 12 x 12 inches. The almost universal practice

in such cases is to use the same frame, crank-shaft, connecting rod, crosshead, etc., for both sizes. This results in relatively stronger members for the smaller engine; but the saving in construction outweighs the small gain in material which would result if all the members of the smaller engine were reduced in proportion to the loads upon them.

It is owing to such considerations as these, which can only be appreciated by one who has observed thoughtfully for years, that the designer must acquire much experience before he can become thoroughly successful. The traditional worthlessness of the young technical graduate is due to his lack of familiarity with the so-called practical considerations. If, when he steps from the college into the shop or office, he is not at once a successful designer, it is not because his ideas are bad, but because he has not enough of them. The school shops and laboratories can be made to do much toward remedying these defects, but the time available for such drill as they afford can never produce the mature judgment required of the well rounded engineer. The education begun in the technical school must be carried on through years of practice. This is no argument against the courses of the best schools; for they give a training which one can scarcely acquire in practice; while the experience and judgment essential to the practical engineer are just the things that are most surely attained in his professional life.

This dual training, that of the college and that of the shop and office, are not in themselves sufficient to produce the highest order of engineer. The engineering genius, like the musical genius, has an inborn aptitude for the work of his profession. But mechanical intuition can be cultivated by drill and observation. Among the most useful methods to this end may be mentioned the practice of sketching and noting dimensions of existing constructions, especially of the product of highly successful designers. When a peculiar form is noticed in a machine member, study it particularly to see if this form was adopted for good reasons, and if some better construction—all essentials considered—could not be substituted. For a most helpful discourse on this subject, the reader is referred to a paper by Mr. John T. Hawkins on "The Education of Intuition in Machine Designing," *Transactions of the American Society of Mechanical Engineers*, Vol. VIII., page 458.

Few engineers can rely safely upon their own experience alone; the successes and failures of others furnish food for re-

flection. Machine design is a composite of art and science; the science suggests the lines of design, and should be applied when feasible as a check; but the element of art often dictates the final forms and dimensions.

Returning to our illustration of the steam engine, we find that certain dimensions can be subjected to analysis and more or less exact computation; but the true value of most of the calculations as to strength is of the nature of insurance. Anyone who has ever compared the proportions of a modern high-speed engine with dimensions calculated by the ordinary formulas of mechanics has been impressed with the apparently high "factor of safety" which is frequently observed; and yet these engines are not free from break-downs. The explanation is that many of the general dimensions actually used have been found necessary in service. They have been adopted to provide for the various elements which can hardly be treated analytically. There are, to be sure, instances in which the dimensions are much beyond the requirements, for it is the practice of some builders to make certain parts much heavier than those of equally successful competitors. This practice may be due to ignorance of the requirements, or is a bid for popular favor through comparison; the presumption usually being in favor of the heavier machine when judged by partially informed buyers. In general, it may be said that mass in the frame and stationary parts of a machine are desirable where there is liability of severe shock; while the moving members should be as light as is consistent with strength and rigidity. Of course this does not apply to such moving members as fly wheels, etc., and there are many exceptions to this rule.

The exercise of individual judgment leads to a wide diversity in the proportions adopted by different designers of similar machines; which is in marked contrast with the general agreement as to certain other proportions.

The writer has been engaged during the past year or two in comparing the proportions of high-speed engines. A partial report of this examination was presented to the American Society of Mechanical Engineers at the recent meeting in New York. The method used was to write to various builders, enclosing a blank form to be filled out with the required data. The information collected was classified, and values substituted in standard formulas, (of a rational form when possible), and the constants were then derived. For example, in studying crank-

shafts, those engines having center, or inside, cranks were treated by themselves, using the formula $d = C\sqrt[3]{H.P. \div N}$; in which d = diam. of shaft, H. P. = rated horse-power, N = revs. per minute. From the data for each engine the value $\sqrt[3]{H.P. \div N}$ was calculated, and plotted as an abscissa; the value given for d being used as the ordinate; these co-ordinates gave a point. About fifty points were obtained in this way, from as many different engines, and lines were drawn to represent the average and extremes of practice. The equations of these lines give values of the constant C for the average and the extremes of practice. The values of the constants as thus obtained are C= 7.56 for the mean; and C=5.98, and C=8.76, for the minimum and maximum, respectively.

In Unwin's Machine Design (Part I, page 225), a similar formula is given, with the value of C assigned as 4.55. This is for marine engine practice, and it serves to show that we must design the smaller high-speed engines on the basis of high-speed engine experience.

Many other examples could be cited to show that any particular constant will not give satisfactory results under widely varying conditions; but the limits of the present paper do not permit further extension, even if such comparisons were within its scope. The above example of the crank-shaft is introduced simply as an illustration. It may be said in passing, however, that the above mean value of the constant for crank-shafts represents very satisfactorily the practice of many leading builders; while in the examination of other proportions, as crank-pin diameters, no such general agreement was discovered.

An investigation is now under way upon the proportions of slow-speed stationary engines, and further work of a similar character is contemplated on other classes of machinery.

It is gratifying to report that a large number of the most progressive builders have co-operated cordially in this examination of the current practice in engine construction. The spirit shown is in marked contrast to that prevalent a few years ago, and it is encouraging to the young engineer as he enters the profession, to feel that his older associates are not all bent upon keeping from him the trade secrets. Of course each manufacturer has much information, acquired, perhaps, by expensive experiment, which he must guard out of self-protection; but the observing young engineer of today, who shows a proper regard for the rights of others, has great opportunities.

DIRECT AND ALTERNATING ELECTRO-MOTIVE FORCES IN SERIES.

BY HORACE T. EDDY, B. E. E.

About a year ago, the attention of the writer was called to a case in which an alternating e. m. f. was superposed on a direct incandescent light circuit. The brightness of the light was not increased very greatly by the addition of an alternating e. m. f. of about half the voltage of the direct current.

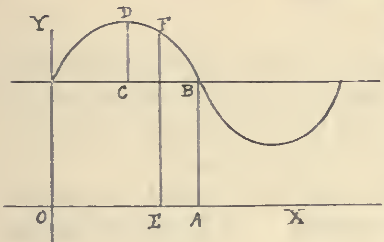


Fig I

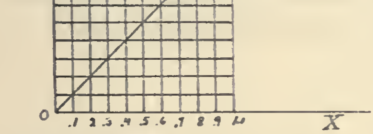


Fig II

On measuring with an alternating voltmeter the e. m. f. of such pulsating currents formed by superposing an alternating on a direct e. m. f., it was found that an alternating e. m. f. of considerable voltage did not greatly increase the voltage of the direct current.

In order to compute the effective e. m. f. of such a pulsating current, let A B in Fig. 1 represent the magnitude of the direct e. m. f., CD the maximum value of the alternating e. m. f., and EF the e. m. f. of the pulsating current at any instant, supposing the alternating e. m. f. to be simply periodic.

The reading on an alternating voltmeter is the square root of the mean square of the instantaneous values of the e. m. f. When applied to a simple alternating current whose maximum value, CD, is equal to a, the reading of the voltmeter is a divided by $\sqrt{2}$. This quantity is positive during one half of the alternation and negative during the other half: consequently, when it is superposed on a direct e. m. f. it increases it dur-

ing one half of an alternation and decreases it during the other half. This is shown in the figure by the fact that the ordinate, EF, is greater than AB during one half of the time and less than AB during the other half.

Now the effective e. m. f., $\bar{y}$ of a pulsating current is, as before stated, the square root of the mean square of the instantaneous values, y of the e. m. f. To compute the numerical value of $\bar{y}$ we have the expression—

$$\bar{y}^2 = \frac{\int (b + a \sin. x) dx}{\int dx}$$ To be taken between the limits 0 and 2π.

$$\bar{y}^2 = \frac{1}{2\pi}\left[b^2 \int dx + 2ab \int \sin. x dx + a^2 \int \sin.^2 x dx\right]$$

$$\bar{y}^2 = b^2 + \frac{a^2}{2}$$

Let us illustrate this result by the case in which $a=100$ and $b=100$ volts. The reading of the alternating voltmeter for $a=100$ will be $100 \div \sqrt{2} = 70.7$, and the reading for the pulsating current will be $\sqrt{100^2 + 70.7^2} = 122.5$ volts.

The relation between the pulsating, alternating, and direct voltages can be shown best graphically. Call the voltage of the alternating e. m. f. $\bar{x}$.

$$\text{Then } \bar{x}^2 = \frac{a^2}{2}; \text{ hence } \bar{y}^2 - \bar{x}^2 = b^2,$$

which is the equation of a rectangular hyperbola as shown in Fig. 2, in which OB $= b$.

It is possible to use a figure like this, drawn on cross-section paper, instead of a table, to find the voltage of a pulsating current arising from the superposition of alternating and direct voltages of any magnitude, for we can write the equation,

$$\frac{\bar{y}^2}{b^2} - \frac{\bar{x}^2}{b^2} = 1$$

Then if we take $\frac{\bar{x}}{b}$, the ratio of the alternating to the direct e. m. f., as the abcissa of any point of the curve, the corresponding ordinate is $\frac{\bar{y}}{b}$, the ratio of the pulsating to the direct voltage, provided OB is taken as unity. But the equation can also be written in the form $\frac{\bar{y}^2}{\bar{x}^2} - \frac{b^2}{\bar{x}^2} = 1$. If now OB be taken as unity, $\frac{b}{\bar{x}}$, the ratio of the direct to the alternating e. m. f.'s,

will be the abscissa and $\frac{-y}{-x}$, the ratio of the pulsating to the alternating voltages, will be the corresponding ordinate to the curve at any point. We can thus read the voltage of the pulsating current, whether the direct voltage is greater or less than the alternating.

The simplest method of obtaining the pulsating e. m. f. is to lay off the direct and alternating voltages at right angles on any scale. The hypothenuse of the triangle with these voltages as sides will be the effective e. m. f.

THE PRINCIPLES OF ARTIFICIAL LIGHTING

BY PROFESSOR GEO. D. SHEPARDSON.

Artificial lighting may be considered under two classes, according as the object sought is *illumination appearance* or *illumination*. In one case it is desired to see the lights themselves. In the other case the objects illuminated by the lights are observed. For light-houses, beacons, and some sorts of advertising, it is desired to have the lights themselves conspicuous. For many other purposes, such as lighting reading desks, pictures, and work-benches, illumination is desired rather than illumination appearance. For some purposes, both illumination and illumination appearance are desired, as for show-window advertising, lighting ornamental stairways and halls, or principal streets.

Illumination appearance is obtained by making the sources of light conspicuous. Familiar examples in Minneapolis are the circles of lights on the towers above the Glass Block and Olson's, the incandescent crosses on the tower of the Wesley Methodist Church, the rows of incandescent lamps along the cornice of the Plymouth and the head-light above the Metropolitan Theatre. A variation is in the use of rows of incandescent lamps forming letters for advertising purposes, such as the signs on the Bijou and Metropolitan theatres, the mammoth Ceresota sign above one of the flouring mills, and similar temporary signs used during the holidays and other festival seasons.

A class of lighting that might be considered as being illumination or illumination appearance or both, is the lighting of translucent signs such as are numerous on any of the business streets, the real source of light being concealed in a translucent enclosure.

Illumination combined with illumination appearance is desired in many cases. Here, again, the advertiser has developed excellent examples, such as the rows of arc lamps along the sidewalks around the Glass Block, the Syndicate Block, and the Plymouth. The arcs call attention from a distance and also light the store-fronts, being behind passers-by on the sidewalk

and high enough not to interfere seriously with the view of those in carriages. Fancy designs in store windows also serve the double purpose, when the lights themselves are not too brilliant, as when colored or frosted lamps are used. An excellent combination of illumination and appearance is found in the street cars. The lights near the ceiling give perfect illumination to those within the car, and also, by shining through the translucent signs, indicate, to those outside, the line to which the car belongs.

For lighting interiors of buildings, especially corridors and halls with high ceilings, excellent effects may be produced by combining illumination with illumination appearance. The rotunda of the New York Life building, and the main entrance to the Lumber Exchange, are examples where the arrangement of lights attracts attention, and yet the illumination is good. The chapel at the University and the lower rooms in the Phœnix Block also illustrate satisfactory illumination for desk work, combined with striking illumination appearance for general effect.

Illumination appearance is often unintentionally and undesirably obtained, when only illumination is desired. In other cases, a certain amount of illumination appearance is desired, but too much is secured.

Illumination without illumination appearance is found in diffused daylight. The prime source of light, the sun, is not seen, but the light is evenly distributed in all directions. The ideal of artificial illumination is to approach sunlight.

The distinction between illumination and illumination appearance, is not as well or as commonly understood as it should be, and frequent blunders are the result.* For instance, the ambitious country town insists on having its streets lighted by brilliant arc lamps, in order, thereby, to obtain a certain metropolitan aspect. Arc lamps are excellent for street lighting if placed not further than one or two blocks apart and if twenty-five to thirty-five feet above the level of the roadway. But, with the not infrequent practice of hanging them eighteen to twenty feet above the roadway and long distances apart, the lamps serve as beacons, to indicate directions and to blind persons in the streets, more than as sources of illumination.

*See paper by A. Scheible on Illumination vs. Glare, *N. Y. Elec. Eng.*, Vol. XX., page 565, Dec. 11, 1895.

An equal amount of money spent in erecting and operating a much larger number of smaller lights, placed at shorter intervals, would better serve the purpose of lighting the roadway with some uniformity and of enabling persons to see the way clearly and safely. For lighting streets and passage-ways, one needs illumination rather than illumination appearance. Similar considerations generally hold true for architectural lighting. One should recognize distinctly the effect sought and then consider carefully the best means of obtaining it.

Having recognized the two more or less distinct classes of lighting, the principles to be followed for obtaining satisfactory results are not difficult to discern.

For illumination appearance, the sources of light should be conspicuous. If dazzling effects are desired, nothing can be more satisfactory than arc lights, either with clear glass globes or with no globes. Calcium or magnesium lights are more troublesome and expensive in maintenance, but may be used in some places. Blinding effects may be enhanced by the use of parallel beams of light from electric search lights of fabulous candle-power. When a general blaze of light is desired, large and numerous gas flames and fireworks have a field almost their own, although the equally liberal use of arc lamps with ground or opal globes, or of incandescent electric lamps, gives magnificent effects. Witness the profusion of light on parts of Nicollet and Wabasha Avenues, or the principal shopping streets of other large cities, also the display illumination appearance at exhibitions and fairs in cities.

A quite different class of illumination appearance, such as is required for illuminated signs, where the lights trace letters or other outlines, involves the use of comparatively large numbers of smaller and less intense lights, so arranged as to give the impression of being continuous lines of light. For such lighting, gas is suitable only in places free from excessive wind and from the presence of inflammable substances. Incandescent lamps with either clear, frosted or colored globes, are peculiarly adapted for such lighting. A convenient method is to mount the lamp sockets in any desired position upon a screen of wire netting.

The principles involved in securing satisfactory illumination with absence of illumination appearance are quite simple, although not always recognized, and although sometimes difficult to apply in practice. The ideal is to keep the source of

light unseen, while the objects of view are sufficiently and evenly lighted. The eye sees various objects by means of the light coming from those objects. If the light from the object is weak, the eye does not receive sufficient light to form distinct images. If the object is too light, the eye partially closes to protect itself. Two similar objects may be illuminated with equal amounts of light, but if one is in the neighborhood of other objects more strongly illuminated, or if a strong source of light comes within the angle of vision, the object with more strongly lighted surroundings will be less distinctly seen than the other one equally bright but with a darker background. If strong lights are in the field of view, the iris of the eye closes so as to limit the total amount of light received. This automatic protective device regulates the opening of the curtain so as to cut the maximum light down to that required by the eye; consequently the light from all objects less bright is reduced in the same proportion.

What constitutes sufficient light depends both upon the purpose of the lighting and the disposition of the sources of light. If the lights are arranged to the best advantage, being suitably distributed and not being seen themselves, satisfaction is obtained if the illumination is equal to that given by one candle at distances indicated in the following table:*

Street pavements or sidewalks	10	feet.
Walls of buildings	8	"
Public halls, churches, theatres, etc., (general light).	3 to 5	"
Workshops (general light)	5	"
Work benches	0.3	"
Tables, reading, eating, etc.,	0.3 to 0.5	"
Corridors, halls, etc.,	2.5	"
Living-rooms	2 to 4	"

The number and size of lights required to give sufficient illumination will vary considerably, being affected by the arrangement of the lights and by reflection from walls, ceiling and objects in room. If the sources of light are in view while one is reading or working, stronger illumination is required than if the lights are out of sight.

For obtaining even illumination, one of the first requisites is that the sources of light shall be out of sight. Unless this is secured, the iris closes so as to accommodate the eye to the strongest light in view, and, consequently, less total light comes

*See paper by Richards in *London Electrical Review*, Vol. XXIX., p. 269, Sept. 4, 1891; also book by Webber on Science and Practice of Lighting, p. 25.

to the eye from the objects of vision. The field of vision is a cone which has the eye for its apex and the outer edges of which make angles with the center line, varying between 50° and 95°. As the eye changes position frequently, the sources of light should therefore be removed outside of a cone considerably larger than the angle of vision; otherwise the eye would be continually accommodating itself to widely different intensities of illumination and would soon tire.

It is too common to have public halls and churches lighted in such a way that one can hardly see the speaker or performer without squinting between or under lights that blind rather than illuminate. A common source of difficulty is that the lights are too low. They should be high enough to be out of the angle of vision of the majority of spectators. Doubtless the drowsiness that regularly creeps over some evening audiences is due quite as much to the brilliancy of the lights as to the dullness of the speaker.

Electric lights are peculiarly adapted to being placed high out of the angle of vision. Incandescent lamps may be studded around the ceiling or along the edges. Recently it has become more or less common to place incandescent lamps behind a translucent cove, or above projecting cornices, so that the lamps themselves are entirely invisible. Another plan, used to some extent with both arc and incandescent lamps, is to have reflecting screens beneath the lamps so as to throw all of the light upward against the whitened ceiling, which becomes a secondary source of light. When arc lamps are used in this way, the lower carbon is made positive, so that the crater throws light directly upon the ceiling. Lamps thus arranged give an evenly diffused daylight effect that is very pleasing, if made strong enough.*

A second requisite for even illumination is to avoid the regular reflection of light to the eye. All bodies reflect light, but with varying intensity. Polished surfaces usually reflect regularly, while rough surfaces reflect irregularly or, in other words, diffuse the light. If one is looking at a polished surface, it is desirable that the source of light be so placed that it cannot be regularly reflected to the eye from the observed surface. Otherwise the reflected source of light comes within the angle

*See paper by B. A. Dobson on Artificial Lighting of Workshops, *London Electrician*, Oct. 27 and Nov. 3, 1893; *N. Y. Elec. Eng.*, Vol. XVI., pp. 513 and 548; also, Dobson in *Cassier's Magazine*, Vol. V., page 417.

of vision. Hence the familiar rule to have the direct light come from over one's shoulder.

This suggests a third desirable condition, namely, that the light come from several sources or from one source of large area. By spreading the source of light over a large area, the regularly reflected light from each element becomes less intense and the glare is correspondingly reduced. For this reason arc lamps for interior lighting often give much better satisfaction when surrounded by opal globes. Although the opal or ground glass globes cut off about half of the total light, yet the apparent source of light becomes many times larger and regular reflection is greatly reduced. Also, if the lamp comes within the angle of vision, the intensity of the source of light is greatly reduced, so that even with less total illumination, objects are more clearly and easily seen. For the same reason, Welsbach incandescent gas lamps are much more comfortable for reading if they are surrounded by diffusing globes. Incandescent electric lamps also give a softer light, when close to one's work, if they are in porcelain or opal globes.

A fourth condition of satisfactory illumination is not to have too great variations in the illumination of different parts of the same area. The human eye was made for long-distance vision*, and, when used for close work, such as reading, it is necessary to rest it occasionally by brief glances toward more distant objects. If the illumination at a distance is far less than that close by, the eye must constantly change the adaptation of the iris and so quickly tire. For this reason, reading rooms and work-shops should have a good general light in addition to the special lights for individual desks or tools.

When illumination appearance is desired as well as illumination, two plans may be followed. Have the lights bright and arranged in striking positions, but so as to be out of the angle of vision, for instance, ceiling lights or arc lamps on sidewalk. Or, if the lamps are necessarily within the angle of vision, have numbers of dim or diffused sources of light, so that no intense light may come from any particular spots.

The foregoing are a few of the principles to be observed in securing satisfactory artificial lighting. Electric lights have

*See paper on Teleopsis, *Denisons' Quarterly*, Vol. II., page 41, 1894.

great advantages over other illuminants*, and render possible certain styles of lighting that are greatly in advance of earlier methods. Further suggestions for applying the principles above noted may be found in the excellent treatises of Palaz† and Webber‡.

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*See paper by Geo. D. Shepardson on Some Advantages of Electric Light, read before Minnesota chapter of American Institute of Architects; *Improvement Bulletin*, Vol. 6, No. 20, April 17, 1896.

†Palaz, Industrial Photometry; especially Chap. 6 on Distribution and Measurement of Illumination.

‡Webber, Science and Practice of Lighting.

ELEMENTS OF METHODS OF METAL MINING, BASED UPON LAKE SUPERIOR PRACTICE.

BY PROFESSOR F. W. DENTON.

Mining operations may be divided in a broad and general way into two classes. The first, technically called "prospecting," has as its object the discovery of a marketable deposit of mineral, and includes the determination of the size, shape, quality, and other characteristics of the deposit. The second class of operations is devoted to the removal of the deposit from its position in the earth to the surface, where it passes from the hands of the miner to those of the ore-dresser, metallurgist or salesman. It is only with a part of the second class of operations that this paper has to do.

In order to lift the mineral to the surface, it is first necessary to establish ways of communication between the surface and the deposit. These are technically termed "shafts" and "adits,"* and as they may be arranged in several ways, are expensive to establish, and must be maintained until the deposit is exhausted, their location will depend upon a variety of considerations. This first step in the removal of the mineral to the surface is of such importance as to usually require a special study. It is called in the text-books the "Winning of the Deposit" or the "Preparatory Work." To obtain a large daily output, it is necessary to make connections with the deposits at numerous points. This is done by making side or branch connections with the deposit from one or more main lines of communication with the surface. Additional points from which the deposit may be attacked are established by extending these branch connections into and through the deposit itself.

As a result of the preparatory work the deposit becomes divided into a series of stories or blocks. If the deposit be narrow, as it usually is in native metal mines, there will be one main drift† for each story; but if wide, as in the case of some

*Shafts are vertical or steeply inclined openings. Adits are horizontal openings connecting directly with the surface.

†Main drifts are the horizontal openings made at the bottom of each story and used as main roads to connect with the shafts and adits.

iron ore deposits, or if in the form of large beds as on the Mesabi iron range, there will be a number of main drifts parallel or at various angles with one another at the bottom of each block or story. When connection with the surface has been established and the deposit has been penetrated by one or more series of these main drifts, the actual work of removal begins and is called "the exploitation" of the deposit, and the system of exploitation followed is commonly known as the "Method" or "System of Mining." It is the object of this article to describe this part of the work of the removal of the deposit, and the considerations which should influence the establishment of a method of mining.

Every method of mining must provide for the following operations:

1st. Breaking the ore, which includes the drilling and blasting.

2nd. Filling or maintaining the cavities formed by the removal of the ore.

3d. Transporting the ore to a shaft or some other connection with the surface.

The order in which these operations have been named indicates their relative importance and also their relative cost.

BREAKING ORE.

This is usually accomplished by drilling holes in the solid ore, into which dynamite or other explosives is placed and fired. The efficiency of the operation is measured by the number of tons of ore satisfactorily broken per dollar expended for the labor, drilling, and explosives necessary. This efficiency will be a minimum when there is but one "free face", and therefore only one direction in which the force of the explosive can act, and when that direction is upwards. The conditions of minimum efficiency for any given material occur in sinking vertical shafts. The conditions of maximum efficiency are several "free faces", large blasts, and an opportunity for the force of gravity to have its fullest effect. Intermediate conditions will give intermediate efficiencies.

The blocks or stories formed by the preparatory work are always mined in descending order; that is, the top block will be completely removed before the second, and the second before the third, etc. The work of removal may be going on simultaneously in several stories, but the top story will always be

the most nearly mined out. This is a natural order, since work will begin first at the top of a deposit considered as a whole, and therefore work should end there first. This order is also the best one for the common systems of mining, and is absolutely necessary in those systems which include the complete removal of any individual block of ore, since such removal will destroy the drifts at the bottom of the block next above. The

PLATE I.—View, from the surface, of the Auburn iron mine on the Mesabi range, showing the miners at work "underhand stoping" or blasting the ore into openings (*raises*) which connect with drifts in the ore body, which, in turn, connect with a shaft not appearing. The ore lies near the surface and is first stripped of its covering.

individual blocks, however, may be mined from the bottom up or from the top down.

The first method of breaking ore to be described is termed "stoping"* and the place where stoping is carried on is called a

* By stoping is meant removing ore in horizontal slices which are usually about eight feet thick; either the top or bottom of the slice is a "free face."

"stope." If stoping is begun at the top of a block it is called "underhand stoping" and if it is begun at the bottom, "overhand stoping." In both cases it is necessary to make a vertical cut or opening from which to begin stoping. In overhand stoping, the opening is begun at the bottom of the block and is called a "raise", and may be extended to the level above, in which event it would be called a "winze."* Overhand stopes are seldom carried at once to the top of the block, but a layer of ore from five to fifteen feet deep is left to serve as a floor for the level† above, or to assist in keeping the walls of the vein apart, or for both purposes. This layer is known as the "floor pillar." Small openings are blasted through these floor pillars at intervals to secure ventilation in the stope. These openings may also be used as a means of getting to and from the stope, and as passages for air pipes, etc. The ore left in the floor pillars may be subsequently wholly or partly stoped, or may be abandoned entirely.

In underhand stopes, the vertical opening from which stoping begins may be driven from the top down, in which case it is said to have been "sunk", or it may be raised as in overhand stoping. Raising would be practiced, if possible, as it is cheaper than sinking, since gravity favors in one case and opposes in the other. In any event the raise or sink will usually become a winze to permit sending the broken ore to the lower level and thus save the extra handling necessary to get the broken ore into cars on the upper level.

Of the two methods of stoping, overhand stoping will give the greater efficiency, since gravity has full play. Another important difference is, that in overhand work the broken ore may be left in the stope to keep the walls from caving and also to serve as a support for the miners and drilling machines. In underhand stoping the ore must be moved as fast as it is broken, as otherwise the solid ore would soon be covered by the broken ore. This results in the formation of a large cavity above the miners, which is always objectionable. Such a place cannot be examined readily for loose pieces of hanging wall rock which are always the most common source of accidents. If the upper level is to be used a timber floor must be put in. Underhand stoping, therefore, is used only to a very small extent. It is employed for removing the floor and other pillars left by the

*A winze is a vertical or inclined opening connecting two main drifts.

†"Level" is synonymous with main drift.

first overhand stope and in open-pit mining. Nearly all stoping is carried on overhand.

Plate I is a surface view of the Auburn mine of the Minnesota Iron Company on the Mesabi range. The deposit is first stripped of its covering and then by underhand stoping blasted and allowed to run into raises placed sixty to eighty feet apart. The raises are about sixty feet deep and connect with drifts

PLATE II.—View in a drift at the top of a raise in the East End mine of the Pittsburg & Lake Angeline Iron Mining Company at Ishpeming, Michigan. A layer of ore has been left above the drift, and the miners are preparing to blast it down. At the right is shown solid ore, and at the back the caved ground which follows the miners down as they remove the ore.

which in turn connect with an inclined double skip shaft. This method of mining is known locally as the "milling" system.

The second method of breaking ore is known as "drifting," and consists in "drifting" or driving comparatively small horizontal openings into the ore. The openings formed are termed "drifts." The first drifts made in a block of ore have but one free face and since the opening is horizontal, gravity is almost neutral, neither assisting nor retarding the work. Therefore, for any given ore, the efficiency of drifting will be less than that

of stoping, and greater than that of sinking. If a second drift be made adjacent to the first, there will be two free faces in this second drift, and other conditions remaining the same, the efficiency of the second drift will be considerably greater than that of the first. Drifting with one side of the drift free is termed "slicing." If directly under a series of drifts, no ore being left between, other drifts be run, these lower drifts will have the top free and some of them one side as well. In the last case the efficiency will be further increased to a small extent. Where the drifting method is used in breaking a block of ore all of the preceding conditions are met with and the efficiency of the whole work will depend upon the relative amounts of favorable and unfavorable conditions.

A third and last method of breaking ore is termed "caving."

The principle in caving is to undercut or undermine a body of ore until, no longer able to support itself, it falls or caves, and in falling becomes broken up, thus accomplishing the results ordinarily obtained by drilling and blasting. The undercutting is usually done by driving a series of drifts in the bottom of the block to be caved, the drifts being adjacent to one another, or with small pillars of ore between. When undercutting has progressed far enough to cause the overlying ore to show signs of settling, the miners will be taken away and the ore left to fall as it will, or more commonly the timber and pillars will be blasted down to hasten the caving. The caving method therefore, involves the use of stoping or drifting for the undercutting. In practice both may be used, although caving is usually combined with drifting. Its efficiency will be a maximum for a particular ore when the drifting or undercutting necessary is a minimum.

A modification of this method is much used in mining the so-called "soft" hematite ores. Instead of undercutting a large block of ore until it falls by its own weight, a small block is only partially undercut, and the overlying ore is blasted down by holes drilled into it from the drifts below. Gravity is thus given an opportunity to assist in breaking the upper portion of the block. Plate II is a view of such work and shows the miners in the act of drilling an "upper" into a layer of ore that has been left above the drift in which they are standing. This modification permits of more regular and systematic work, since the ore is brought down in small quantities at a time and the fall of the ore is more under the control of the miners.

It is less efficient than the first method, however, and is only applicable to shallow blocks. Probably not more than ten feet of ore over the drifts can be advantageously mined in this way.

Caving hard ground, in order to break it up and thus avoid the expense of drilling and blasting or filling the cavities formed by the removal of ore, has reached a high state of development in the Lake Superior region. This method has saved many tons of good ore which otherwise would have been lost, owing to the greater cost of removing it by the older methods. It is applicable even to the hardest ores under favorable conditions. Unless well applied however it may cause the loss of considerable ore. Such loss is usually caused by the upper portion of the caved ore becoming mixed with the overlying earth, sand, or barren rock, which, of course, settles or falls with the ore. When the block of ore to be caved is thick, the overlying rock weak, and there is nothing between the rock and the ore to separate them, the loss from this cause may be very large. If, however, by previous work, a mattress of crushed and broken timber has been formed between the top of the block and the overlying rock, the loss of ore from mixing may be no greater than in other methods of breaking.

Of the three methods of breaking ore, stoping, drifting and caving, overhand stoping will give the greatest efficiency if we consider only the breaking of the ore. This is especially true in the case of very hard ores which are difficult to break, and with such ores the method of breaking is the most important factor in the system of mining. The greater efficiency of stoping becomes less marked as the ore becomes softer, and finally stoping ceases to be applicable to very soft ores, which either have a tendency to run, or under which it would be dangerous for men to work. In soft ores, therefore, drifting is used, and becomes the only practicable way of removing the ore.

For ores intermediate between very hard and soft, the breaking may be done by any of the three methods, and it is in dealing with ores of this class that the greatest skill and experience are called for. In such ores the superior efficiency of stoping is not so marked that the breaking of the ore is always the most important factor in the system of mining, and therefore efficiency in breaking may be sacrificed to increase the efficiency somewhere else. The efficiency of caving is intermediate between that of stoping and drifting, and caving is used chiefly to reduce the cost of breaking ore when the conditions are unfav-

orable for stoping, and the ore hard and therefore expensive to drift in.

FILLING AND MAINTAINING CAVITIES.

The removal of ore produces cavities, or chambers, in the deposit which must be taken care of in some way, for, if allowed to increase indefinitely, Nature will surely fill them eventually; perhaps by sudden and extensive caving, which would be both dangerous and costly.

Cavities are filled naturally in one of two ways: Either a

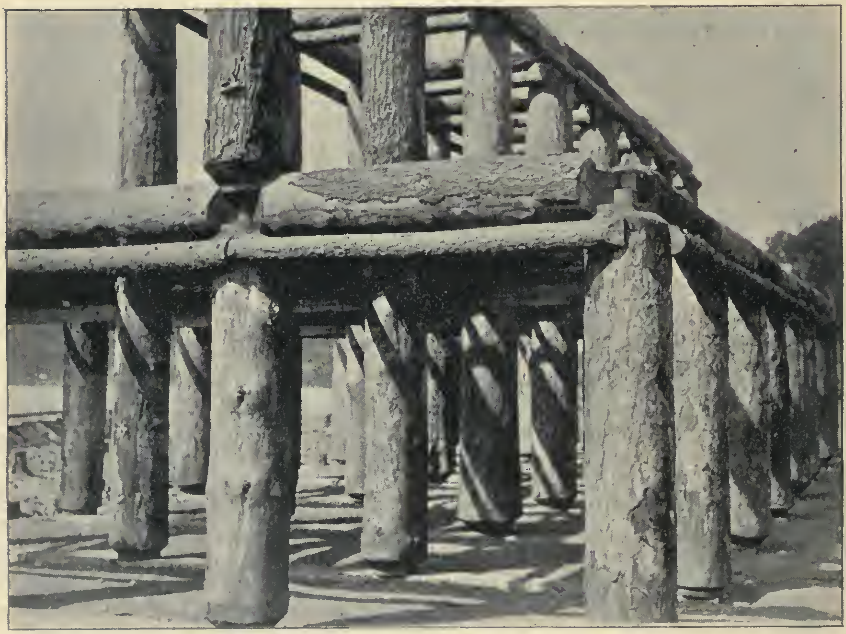


PLATE III.—View of square set timbering cut by machinery and formerly used in the Lake mine of the Cleveland Iron Mining Company at Ishpeming, Michigan.

large mass of the overlying ground settles, filling the cavity completely, or comparatively small pieces of the roof and walls fall at intervals and, by accumulating, eventually fill the cavity. As soft and hard ores may occur, surrounded by either hard or soft ground, the treatment of cavities formed by the removal of ore may become a difficult and important matter.

In dealing with cavities in any kind of material, the object should be to make them as self-maintaining as possible. This is accomplished by leaving sufficiently solid side walls and arching the back or roof. There is a large class of soft grounds in

which, if a chamber with a flat roof be excavated, the roof will fall piece by piece until it has reached an arched form, and then remain intact for an indefinite period. In a similar manner it is possible that a wide drift with a flat roof may be run in a soft ore-body with safety, and yet after the drift is timbered, a considerable weight may be brought upon the timber by the settling of the material below a natural arch in the roof of the drift.

Ground is strongest usually when freshly exposed, which

PLATE IV.—View of square set timbering employed in the Calumet and Hecla mines, Michigan. The original negative was made by Mr. J. M. Vickers, of Ishpeming, who has kindly consented to its reproduction.

explains why flat roofs will stand for a while and then fall. If soft ground therefore, is to be left unsupported for a considerable time after it has first been exposed, the roof should be arched. Even when timbering follows closely after mining, it may often be advantageous to arch the roof to avoid pressure upon the timber. It is by the formation of these natural arches, com-

bined with the cohesive strength of the ground, that all large cavities are maintained.

A simple calculation will show the impossibility of supporting ground by timber alone at depths of several hundred feet below the surface. The maintenance of cavities is no more difficult at depths of several thousand feet than at depths of three or four hundred feet. In fact, the greater difficulty is likely to be experienced near the surface, owing to the presence of water and lack of homogeneity of the ground. The limits of cavities in any given material will be fixed, therefore, by the self-sustaining qualities of the ore and the surrounding ground, and when these limits are reached the cavity must be caved by the blasting of the roof, filled by introducing broken rock and sand, or simply abandoned. When the conditions render caving practicable, this method of dealing with cavities will usually be followed as being the cheapest. Caving large chambers, also called "rooms," is, however, more or less uncertain in its results. When practiced, the caving is accomplished by blasting out the timbering of the room a short distance above the floor, if the timber shows considerable weight, and if it does not, by blasting both timber and roof. If the cavity is filled with broken rock or sand, the filling is obtained as cheaply as possible, and is introduced with a minimum amount of handling.

The filling material may be obtained from the surface, or it may come from some point in the mine where the rock is soft and easy to blast. If the hanging wall be easy to break, raises may be carried up into it dipping 45° with the horizontal and located at small intervals along the strike, and from these raises rock may be blasted and allowed to run into the adjoining cavity. At a mine in Michigan, sand filling is obtained on the surface close to the shaft and carried by an endless rope system of haulage to the top of the shaft where it is dumped into a large iron pipe which delivers it at the different levels in the mine, whence it is trammed to a raise connecting with the cavity to be filled. If the conditions allow the filling material to be obtained directly at the top of the raises leading to the places to be filled, the filling method of dealing with cavities may be the cheapest. If, however, this favorable condition should not exist, or if it be necessary to pack the filling close to the top of the cavity, or for any other reason to handle it extensively, this method may become too expensive to be used, and if caving be

impracticable the cavity must simply be abandoned as soon as the natural limits are reached. If abandoned, the walls, which are usually composed of the ore or valuable mineral, must be abandoned also, and unless removed by subsequent work of a different nature the loss from this source may reach as high as sixty per cent. of the total mineral. Thus far it has been assumed that only large masses were to be dealt with. It may also be necessary to support small pieces that have become detached from the roof and walls by blasting, movement of the ground, or weathering. This kind of support is given chiefly by various styles of timbering, the functions of which may be classed under the following heads:

First, to protect men and to maintain openings by keeping back loose pieces of ground.

Second, to act as a staging or support for the miners and their tools.

Third, to give warning of approaching danger from caving.

The style of the timbering will depend upon the special conditions of each mine. The common forms of timbering are known as props, stulls, cribbing, square sets, and drift sets. Props are usually temporary timbers used for holding up isolated pieces of loose ground while the main timbering is being put in, or the ground blasted; they are generally placed vertically and are of light timber. Stulls are large, permanent, carefully fitted timbers that are used to support isolated pieces of ground that have been exposed by the removal of the ore; they always extend from foot to hanging wall, and are placed at angles slightly above the perpendicular to the plane of the dip. If the ground is very heavy these stulls may be placed in groups, called "batteries". In setting up both props and stulls the pressure upon the timber should be uniformly distributed, in order to get the maximum resistance from the timber and avoid splitting. This is accomplished by the use of wedges, which are tightly driven between the ends of the timber and the rock. If well set up, stulls will not fail by splitting or falling. If a battery of stulls is not sufficient to keep the ground up, cribbing may be used. Cribbing consists of timber from 6 to 12 inches in diameter and 6 to 20 feet long, piled log-cabin fashion. The pile is made at right angles to the plane of the dip, and if the dip is steep the timbers are slightly notched or spiked, to keep them in place until the pressure comes upon them. This support is made many times stronger by filling the interior of

the pile with broken rock, which converts it into an artificial pillar. If, when filled, cribbing will not hold the ground, the case comes under the conditions of the first part of the discussion of cavities and must be handled accordingly.

When the vein becomes too wide to permit the use of timbers extending from wall to wall, or when the whole roof needs support, a different style of timbering is used and is known as

PLATE V.—The view is taken at the end of the ninth level of the Minnesota hard hematite mine on the Vermilion range. The first "drift stope", 18 feet high and the full width of the deposit, has been made, and drift timbering is being erected to maintain an opening through the filling which will precede the taking off of another stope or slice.

"square sets". Square sets are of two general classes; one having the main timbers always horizontal and vertical, the other having them parallel and at right angles to the plane of the dip. Plate III shows the first class. Horizontal timbers are either called "caps", if they are all alike, or "caps" and "studdles" if of two kinds, and the vertical timbers are called "legs." Plate IV shows the second class. In this the nomenclature is not so simple since there is a greater variety of pieces which require

many names to distinguish them, and such names will generally have a local significance only. In the first class of square sets the practice on Lake Superior is to leave the timbers round. The joints are generally cut by hand although one very complete mill has been erected for cutting timbers like that shown in Plate III. The style of joint varies at each mine, the chief difference being in the matter of tenons. Some have tenons on both ends of the legs, some on the bottom or top only, and some have no tenons at all. In the one example of the second class of square sets that exists on Lake Superior shown in Plate IV, the timber is sawed to 12x12 inches. There is no hard and fast rule for deciding which class of square sets should be used. Two considerations would probably influence a decision; first, the probable direction of the maximum pressure upon the timber, and second the ease of fitting the timber to the cavities formed. It is impossible to predict exactly in what direction the maximum pressure will come, but if we have a hard deposit 20 to 40 feet thick and dipping at an angle of 45° or less, with a weak hanging wall, we can safely say that there would be considerable side pressure upon a vertical system of timbering.

To fit the first class of square set timber between parallel walls dipping at 45° or less and only twenty to forty feet apart, a great deal of special cutting and fitting will be necessary to make a good contact between the walls and the timber. On the other hand, if the second class of timber is used for such conditions, the fitting will consist of short props and blocking inserted between the limits of the regular system of timber and the walls. When the walls are not well defined or are not parallel, and the cavity is wide, and both top and side pressure are to be expected, the first form of square sets will be employed with the addition of diagonal bracing placed to oppose the side pressure.

Drift sets, as the name implies, are used to support ground in drifts and usually consist of three pieces, two legs and a cap. Formerly, a fourth piece, known as a "sill" or "mud sill," was used, upon which the legs of a set rested, to prevent them from sinking into the bottom of the drift. At present, however, sills have practically gone out of use, except in cases of very soft ground, it having been found that legs sawed square at the bottom stand well enough. The sills were placed either across the drift, the two legs of any one set resting on the same sill, or parallel to the sides of the drift. The method of placing the sills de-

pended upon the method of supporting the tram rails and of timbering rooms opened out from the sides of the drift. The joints of drift sets are designed to suit the pressure expected, which may come from the top or side, or from both directions.

For main drifts or levels, which must be maintained for a long time, the largest timber available is often used, the diameter varying from ten to thirty inches. Plate V shows main drift timbering. For smaller and secondary drifts, often called sub-drifts, and for drifts used to extract ore only, the timber seldom exceeds nine or ten inches in diameter. The pressure upon the caps of the main drift sets may often be so great that considerable timber has to be replaced before the drifts can be abandoned. It would seem that for such cases the use of iron or steel I beams, or of common rails, would be advantageous. These iron beams will support a great deal more pressure than the timber usually available, without consuming so much head room. Such iron and steel beams have been used in foreign countries with apparent success. In all kinds of timbering small sticks of timber called "lagging" may be placed between the heavy timbers and the ground to distribute the pressure, or to support small, loose pieces, that otherwise might fall. Lagging consists either of natural round poles, four to ten inches in diameter at the butt, or of such poles split into halves, and extends from one timber to the next.

The first object of timbering, to protect the men and maintain the cavities, is accomplished by some of the ways which have just been briefly described. It may be made to serve as a staging for the miners and their tools by the addition of a few planks laid across the timbers or spiked to them, and in this way its second object is accomplished. The third object, to give warning of approaching heavy caving, is attained by erecting the timber in such a manner that it will show any movement in the surrounding ground. To do this there must be as many points of contact between the timbering and the surrounding ground as possible. This contact can be best obtained by the liberal use of blocking between the lagging, or the main timbers, and the ground. If large cavities occur back of the timber they should be promptly filled with cordwood or similar material. Ground rarely falls or caves without giving some warning by cracking, moving, or spalling, but such warning can easily pass unnoticed unless the timbering is affected. Well blocked timber will not only show by incipient crushing or cracking that the

pressure upon it is increasing, but will also resist such increased pressure longer than loosely erected timber.

Dimensions of timber naturally vary with the character of the timbering, weight to be borne and available supply. Props are usually small, 8 to 12 inches in diameter, and 3 to 10 feet long, and of any kind of timber. Stulls may be from 8 to 40 inches in diameter and 4 to 20 feet long. When the largest diam-

PLATE VI.—The view is taken in the Minnesota mine, on the Vermilion range, and shows the method of loading cars in the main drift at the bottom of the filling. These loading chutes are established at intervals of 25 to 40 feet.

eters are needed, the weight of the stull becomes an important factor and limits the kinds of timber to be used to those of low specific gravity, usually to white pine. In square set timbering the diameter of the timber will be from 10 to 30 inches, with an average of about 14 to 16 inches. As previously stated, the inclined square sets described are made of sawed lumber 12x12 inches. The most important dimensions in square set timber of any kind are the lengths of caps and legs. These regulate the size of a set of timber and the size determines the

number of tons of ore procured per set of timber, and therefore the cost per ton for timber. Sets are generally cubical in form, and the length of a side, center to center of timbers, varies from 5 to 8 feet. Five-foot sets will displace 125 cubic feet each, or 7 tons, allowing 18 cubic feet per ton. An eight-foot set, making the same assumptions, would displace about 28 tons with the same number of joints to be cut and only a small amount of additional timber. The cost per ton for timber of this description therefore will decrease quite rapidly as the size increases. Large sets require ground that will stand well while the timber is being erected, and are more difficult to handle than the small sets. Economy, however, has encouraged their use and the modern tendency, although against the square set system of timbering as a whole, favors the large sets where the system is still employed. If properly laid out and executed, square sets are reliable and economical especially for the so-called "soft" hematites which are expensive to break in any way except by overhand stoping. Cases of sudden and complete collapses of this kind of timbering have given it a reputation for treachery which is not altogether warranted. Theoretical considerations tell us that such timber must be carefully erected, and that it is strongest when in perfect alignment. A pressure that is great enough to move the timber a small amount out of line will usually be sufficient to effect its complete collapse eventually.

The expense of cutting tenons upon the ends of the legs has caused tenons to be abandoned at some mines. Whether tenons are really necessary or not is difficult to decide, but in the writer's opinion the strength and reliability of square sets are largely dependent upon the stiffness and accuracy of the joints, and stiffness is certainly increased by tenons on the legs. Whatever the form of the joint, however, it should be accurately cut and the timber erected with care and well blocked against solid ground on all sides.

The handling of timber about a mine is a detail of considerable importance. The fundamental rule is, never to hoist timber unless absolutely necessary, but if possible connect the place to be timbered with the level above and send the timber down from this level to its final position. This is not only the cheapest method of handling the timber when it is practicable, but it is the most convenient as the ore mined is sent to the level below and the two do not interfere.

There is a special method of maintaining cavities which is used as a substitute for timbering and which should be mentioned in this connection. If the vein is hard and of low grade, and the hanging wall weak, a layer of from 2 to 5 feet of the vein may be left attached to the hanging wall to support it, and thus save the cost of timbering. This method is practiced in some of the low grade copper bearing conglomerates of Michigan, which are invariably associated with weak hanging walls. The adoption of the system, of course, will depend simply upon the relation of the cost of timbering to the value of the mineral left.

TRANSPORTATION OF ORE TO THE SHAFT.

The general principles in handling ore are to hoist it but once and then only in a regularly equipped shaft, and to avoid shoveling as much as possible. To comply with these rules ore broken between any two levels must be sent down to the lower level and thence to the shaft with as little handling as possible, gravity being utilized to the fullest extent.

The method of transportation, it is evident, will depend upon the dip of the deposit and the method of breaking the ore. When overhand stoping is used and the dip is steep enough, the ore is allowed to fall to the lower level where it is loaded into cars and trammed to the shaft. The loading will be cheapest if the broken ore is stopped just above the level of the top of the cars and then by means of chutes run into the cars by gravity. The conditions which usually prevent such an arrangement are too flat a dip and pieces of ore too large to be dropped into the cars without injuring the latter. A flat dip is sometimes impossible to overcome, but modern practice seems to favor overcoming the second difficulty by building cars of special construction to withstand the great shock of the falling pieces.

As several stopes may be opened from one level it is usually necessary to maintain a clear road under the several stopes. This is done by the use of timbers. If the vein be narrow enough and the walls good, a row of stull timbers will be used backed by lagging; if wide, drift sets. Plate V shows the timbering used to maintain an opening under the filling in the Minnesota iron mine. Blasting may be safely carried on above such timber if the timber be kept covered with a few feet (5 to 15) of broken ore or rock. This broken ore acts as a cushion and absorbs the shocks of the falling pieces, keeping the timber

intact and making it possible to break and tram ore from a given place at the same time. If the dip be too flat or other conditions unfavorable for the establishment of loading chutes at regular intervals, a platform may be erected along the side of the drift at the level of the top of the cars, and the broken ore allowed to run out upon this platform, from which it may be shoveled or rolled into the cars.

When the ore is broken from the top down, as in the drifting method, it is necessary to transport the ore from the end or "breast" of the drift, where it has been broken, to the top of some raise or chute leading to the level below. For such transportation wheelbarrows are commonly used and occasionally small and light tram-cars holding from one-half to one ton. It is perhaps unnecessary to state that this kind of transportation should be a minimum and, if possible, the raises or chutes should be near enough together to permit shoveling the broken ore directly into them.

The cars used for transporting ore, as already indicated, are designed to suit the method of loading and the character of the ore. The material used in car construction is of high grade, and more attention is now being paid to car construction than heretofore. Steel plate, varying in thickness from 3/16 to 1/2 of an inch, is being used, the bottom being made of plate 1/8 of an inch thicker than that of the sides. If the cars are to be loaded with hard ore from chutes, the truck is usually made up of two forged axles and two heavy longitudinal timbers, which are intended to reinforce the bottom plate and absorb the shock. Also, the box of the car may in such cases be made shallow, in order to lessen the free fall of the ore. If the ore be allowed to roll out on the floor of the level, it must be lifted into the ore cars, and in such cases the cars will be as low as possible, and either open at both ends or provided with doors, one of which at least will be hinged at its lower side and thus open downwards, permitting its use as an inclined plane to assist in loading large pieces. In soft ore mines, and in hard ore mines where the loading is not done from chutes, cars made entirely of metal are used. Both inside and outside bearings are used, and generally self-oiling wheels.

To further diminish the car resistance, wheels of large diameter are employed, 14 and 16-inch wheels being used. More attention is being paid in the Lake Superior district to tram-cars and tramming than ever before, and a tramming cost

higher than five to seven cents per ton is considered warranted only by very exceptional circumstances.

Mechanical transportation is represented by electric motors, compressed air motors, and endless rope haulage. Mules are also employed in the iron mines of Minnesota. The independence of the compressed air motor gives it a decided advantage in metal mines where a block of ground may be mined out in a short time, or where it may be difficult and expensive to install or keep running a rope or electric system.

At the shaft the ore may remain in the cars and be hoisted directly to the surface by cages, or the ore may be dumped into pockets at the shaft and subsequently loaded into skips by gravity. The shaft-pocket-and-skip method is a favorite one among the iron mines and seems to be growing in popularity. The method makes tramming and hoisting independent of each other, at least for a short time, and permits each to be arranged to the best advantage.

It will be seen from this brief and general description of the three main operations included under "Methods of Mining," that when a special deposit is under consideration, the adoption of a method of mining it may be either a very simple matter or a complicated one. Conditions favorable to cheap breaking may be very expensive to maintain or may be directly opposed to cheap work elsewhere, and so a method has generally to be adopted which is a compromise between conflicting conditions. The efficiency of any method as a whole must finally be determined by the cost of a ton of ore delivered at the shaft.

NOTES ON THE DESIGN AND MANUFACTURE OF DYNAMO ELECTRIC MACHINERY.

BY C. H. CHALMERS, '94.

It is the purpose of this article to treat briefly of a few points in the design and manufacture of dynamo electric machinery that have come to the notice of the writer. Particular attention will be paid to considerations which the technical press and text books regard as of minor importance.

No logical order or arrangement will be attempted, the different items being discussed without reference to each other.

ARMATURE DISCS.

These discs are usually made from soft charcoal iron or a mild steel and generally run about fifty to the inch. Little or nothing seems to be gained by making them thinner, while on the other hand, if this thickness is exceeded, the losses from foucault currents cause excessive heating. Much has been said about insulating the discs from each other by means of paper, varnish, etc. It is now the practice of the leading American manufacturers to build up their armature cores without any other insulation than the oxide which is on the discs. The writer found his company using paper insulation on all their cores when he took charge of the design and testing of the apparatus. In order to be absolutely certain he had two ten H. P. armatures built, one with paper and the other without. These, before being wound, he ran for several hours in a strong field and noted carefully the rise in temperature of each. He found no difference whatever. They have used no paper in their cores since, and have noted no change in the action of the armatures.

Armature discs are sometimes punched and sometimes cut out with a set of tinners' circular shears. Unless the punch is kept in first class order, the edges of the disc are apt to be frayed and rough, while the shears make a clean cut every time. These shears are much less expensive than the punches, and, when once adjusted for a particular disc, can be operated by cheap labor.

For small armatures, the discs may be cut out in squares and turned off in the lathe. A side cutting tool can be used so that two or three cuts will finish the armature. The finishing cut should be a thin one, to avoid burring the discs together. Toothed armatures are made in a variety of ways. The larger factories use punches, while the smaller ones make the slots with a shaper, planer, or milling machine.

HEADS OF ARMATURES.

Closely allied to the subject of armature discs is that of the heavy discs or heads which are usually put on each end of the armature to give it strength. For this question there are three solutions; I. A heavy disc of mild steel, wrought iron, or cast iron; II. A similar one of brass, gun metal, or some other non-magnetic metal; III. The use of no head at all. The use of the iron disc lowers the magnetic density in the armature and in this way tends to decrease the losses due to hysteresis and foucault currents; on the other hand, being thick, it is in itself subject to heavy parasitic currents and consequent loss. A little reflection will reveal the fact that these losses will be principally due to eddies.

The permeability of the iron disc increases the voltage available for causing eddies, while its ohmic resistance tends to reduce the currents which naturally flow. Taking the armature head by itself, it is evident that the lower the permeability and the higher the ohmic resistance, the less will be the heating of the head.

The loss due to eddies is:

$$(1) \qquad W = \frac{E^2}{R}$$

Where W equals Watts, E equals volts, and R equals ohms. But E in a given case varies directly with the permeability, so that

$$(2) \qquad W \propto \frac{U^2}{R}$$

Where U equals permeability. Equation (2) shows the great advantage of the brass or gun-metal head.

The permeability is reduced from the square of a very considerable quantity to unity, while the ohmic resistance is increased an amount which is negligible when compared with the gain due to the decreased permeability.

These considerations have led to the adoption of brass heads on many machines, and to a subsequent decrease in the

heating of the armature. It has long been recognized that an armature without heavy discs at the ends, would be the best and only true solution of this question, but it is only recently that manufacturers have built their armatures without heads or heavy discs at the ends. Of course only ring type armatures are built in this latter way..

RELATIVE LENGTH OF FIELD AND ARMATURE.

As machines are built nowadays, every little detail that will tend to make the machine run cooler is worthy the attention of the designer. In well designed machines the heating, rather than sparking, is the limiting factor in the load, which the machine will safely carry. The armature must be laminated in planes that are parallel to the induction, for by so doing the interstices are placed directly in the path of the foucault currents. An examination of Figs. 1 and 2 will show the effect of the relative length of pole piece and armature core, so far as concerns the magnetic induction. In Fig. 1, the lines of force are shown as entering the end of the armature in a direction normal to the lamination.

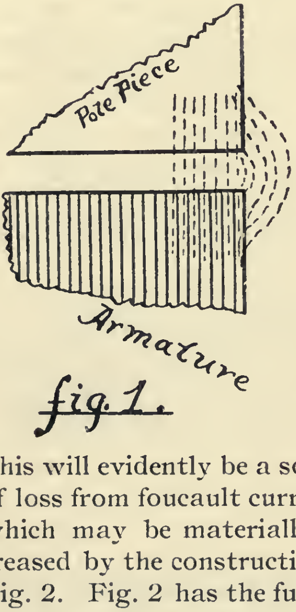


fig. 1.

This will evidently be a source of loss from foucault currents, which may be materially decreased by the construction in Fig. 2. Fig. 2 has the further advantage of increasing the cross section of the air-gap with a consequent decrease of the energy needed for exciting the field. On the other hand, Fig. 1 has an advantage in that the conductors on the surface of the armatures are shorter and the C^2R loss less. There seems to be no definite rule among authorities regarding the ratio of length of armature

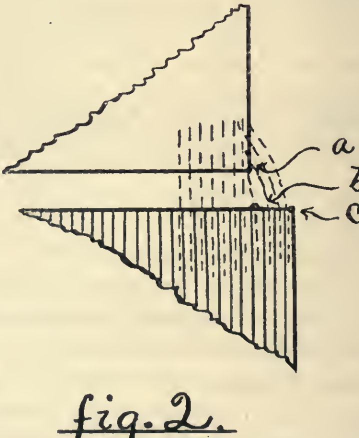


fig. 2.

and pole piece, but it would seem a rational solution of the question to make *ab* equal *cb*, see Fig. 2, or at least nearly so.

ARMATURE SPIDERS.

The mechanical design of armature spiders is usually considered to be identical with that of an ordinary fly wheel. Large factors of safety are used so as to have ample strength in case of a short circuit on the machine. The revolving armature is treated as the rim, and the spider as the hub and spokes, of the wheel.

The enormous kinetic energy which must be contended with in case of a heavy short circuit is given as the reason for the large factors of safety generally used in spider designs. A careful study of the conditions in cases of the above nature will show that this method of procedure in the mechanical design of armature spiders is radically wrong. If we assume that the armature is brought to a dead stop in a given time, we can compute the kinetic energy by the formula:

$$K = \tfrac{1}{2} M V^2,$$

where K equals foot pounds, M equals mass, and V equals the velocity in feet per second.

The first impulse is to use M as meaning the mass of the revolving core and conductors, but this is just where the mistake lies. The mass to be considered is *not that of the armature*, but that of the shaft, pulley, belting, and moving parts of the engine.

The major portion will of course be the fly wheels of the engine, and this will suggest that an engine with heavy fly wheels and moving parts will be more severe on a generator in case of a short-circuit than one where corresponding parts are light. Of course, so far as concerns the strength needed to transmit the strain from the shaft to the core in ordinary running at full load, or considerably beyond it, is concerned, the mechanics of the cantilever is of prime importance.

STRENGTH OF CONCRETE AND STEEL IN COMBINATION.

BY PROFESSOR FRANK H. CONSTANT.

Within the past few years the use of concrete and steel in combination has become quite common.

We see it first coming into extended use with the advent of the modern steel foundation for tall buildings; we find it applied to the solid floors of bridges and buildings; and later we see it appearing as the principal element of certain kinds of arch bridge constructions known as the Monier and Melan Systems.

By concrete-iron construction is meant such cases in which the two materials, by their combined resistance, carry certain specific loads. With the increased use of concrete in combination with steel or iron, a study of the elastic properties of the combination becomes correspondingly important.

Unfortunately, our knowledge of this subject is as yet extremely limited, owing to the few experiments that have been made to determine the elastic behavior of cement or concrete under varying conditions. The tests that have been made upon various types of concrete-iron construction, were conducted for the purpose of determining the ultimate strength of certain forms, rather than as a scientific interpretation of the mechanical laws governing such construction.

Generally, in large and important structures subjected to heavy loads, such as foundations and Melan arch bridges, the steel portion is made sufficiently strong to carry the entire load. In such cases, the concrete serves as an additional factor of safety. The writer would not advocate a change from this custom, for concrete, as it comes from the hands of the ordinary shift of laborers, is too uncertain a quantity upon which to place the safety of a structure. Nevertheless, with proper supervision, excellent concrete may be produced, which may aid materially in the strength of the structure. Especially is this true when the concrete is so placed in the combination as to develop its compressive strength simply. The compressive resistance of concrete being quite large compared with its tensile

strength, considerable latitude might be permitted before its usefulness is destroyed.

The strength of two elastic materials in combination depends upon the relative elasticities of the two substances. The coefficient of elasticity of steel is about 30,000,000, while that for ordinary concrete varies from 750,000 to 2,000,000, but which, in what follows, we will take at 1,000,000.

Now the stresses developed in different materials under like conditions, are directly proportional to their coefficients of elasticity. Thus, suppose bars of cement and steel are placed side by side in a testing machine and subjected to the same pull and stretch. Then the actual stress developed in the cement will be but one-thirtieth of that developed in the steel. In other words, the cement will resist one-thirty-first part of the total pull. To make this illustration more clear, substitute for cement a bar of rubber.

Let us first consider the very common condition (occurring in foundation work, and in the Melan Arch) of a beam buried in concrete. (See Fig. 1.) As the formulæ which we are to obtain are to be working formulæ, we will assume that the steel is not strained beyond the elastic limit. Two cases must be considered: *a.*—When the concrete does not crack, and when the steel does not pass the elastic limit. *b.*—When the concrete cracks on the tension side, but the steel does not pass the elastic limit.

Should the concrete fail on the compression side also, the condition becomes that of the steel beam acting alone. In each of these cases the controlling fact is that the adhesion between the concrete and the steel is assumed to be sufficient to cause equal distortions in the two materials; that is, the radius of curvature under flexure is, at any point, the same for both materials. In order that this condition may be satisfied, the beams should not be spaced very far apart.

CASE I. (See Fig. 1.)

Let M'' = moment of resistance of the concrete,
M' = moment of resistance of the steel beam,
r = radius of curvature of both, under flexure,
E'' = coefficient of elasticity for concrete,
E' = coefficient of elasticity for beam,
I'' = moment of inertia of concrete,
I' = moment of inertia of beam.

b = width of concrete,
h = depth of concrete.

Then,
$$\frac{1}{r}=\frac{M'}{E'I'}=\frac{M''}{E''I''}$$

$$\frac{M'}{M''}=\frac{E'I'}{E''I''}=\frac{30\,I'}{I''}$$

$$\therefore\ M''=\frac{M'I''}{30\,I'} \qquad (1)$$

M' and I' can be obtained from the handbooks of steel manufacturers, and $I''=\frac{1}{12}bh^3$. The total moment of resistance of the combination is,

$$M=M'+M''=\text{external moment.}$$

To find the extreme fibre stress in the concrete:

$$f''=\frac{M''h}{2I''} \quad \text{and} \quad f'=\frac{M'h}{2I'}$$

$$f''=\frac{M''I'f'}{M'I''}=\tfrac{1}{30}f', \text{ where}$$

f'' = extreme fibre stress in concrete,
f' = extreme fibre stress in beam.

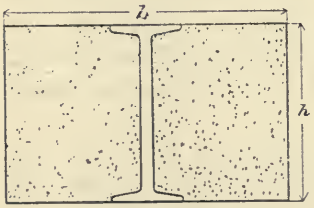


Fig. 1.

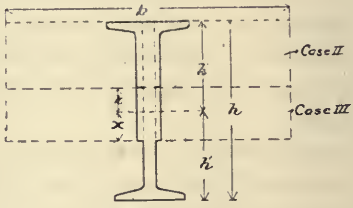


Fig. 2.

This last result is evident from the fact that fibres in the concrete, and in the steel, situated at equal distances from the the neutral axis, must have equal distortions, and hence the fibre stresses are proportional to the coefficients of elasticity of the two substances. Since the fibre stress in the concrete is at all points but one-thirtieth of the corresponding fibre stress in the steel beam, we might, without changing the total amount of stress in the concrete, have considered the width of the concrete reduced to one-thirtieth of its former width, while the fibre stress at each point is increased thirty-fold so as to be equal to that in the steel beam at the corresponding point. The concrete, which has thus been metamorphosed into a steel beam of one-hirtieth of its former width, may now be considered as part of

the steel beam and its properties obtained in the ordinary manner. This method will be used in the solution of the next case.

If the ultimate tensile strength of concrete be taken at 200 pounds per square inch, the corresponding fibre stress in the beam should not exceed 6,000 pounds, in order that the concrete may not crack. Should the beam be subjected to the usual working fibre stress of about 15,000 pounds per square inch, the corresponding fibre stress in the concrete will be 500 pounds, which, while great enough to crack the concrete on the tension side, is well within the limit of its compressive strength.

This first case is of importance in the consideration of such forms of elastic arch construction as the Melan arch, where a reversal of stress is possible. In this case, should the tension, which may occur at different times in either flange, exceed 6000 pounds, cracks may start from both sides and pass entirely through the concrete, thus seriously impairing or destroying its value as one of the elements of strength in the structure.

CASE II. (See Fig. 2.)

In this case we shall assume that the concrete cracks on the tension side, and owing to vibration or other causes, the crack extends to the neutral axis. In other words, we shall assume that none of the concrete is in tension.

The special difficulty in this case is that the neutral axis is now no longer in the center of the beam, but has moved toward the compression side a small distance k. The value of k, however, can readily be found as follows:

As was shown in Case I, the concrete may be replaced by a strip of steel, having a width equal to one-thirtieth of the width of the concrete. This substitution does not affect the total amount of stress in each small horizontal layer and hence does not disturb the condition of equilibrium. This strip becomes part of the steel beam and we have now to deal simply with the modified steel beam shown in the figure. The neutral axis is in the center of gravity of the figure and may be found by dividing the moment of the area of the additional strip about the center of the beam by the area of the entire figure.

Let A = area of steel beam.

I' = moment of inertia of steel beam about its own center.

I'' = " " " strip about the new neutral axis of beam.

$I''' =$ moment of inertia of steel beam about the new neutral axis.

$k =$ distance from neutral axis to the center of beam.

$h' = \frac{1}{2}h.$ of beam.

Other quantities have the same values as for Case I.

Then $$k = \frac{b(h'-k)\left[\frac{1}{2}(h'-k)+k\right]}{30\left[A+\frac{1}{30}b(h'-k)\right]} \qquad (2)$$

whence $$k = \frac{bh^2}{4(60A+bh-bk)}$$

This equation can readily be solved by trial, as bk is a small quantity.

Thus, if $b=24''$; $h=15''$; $A= 12''$; then, $k=1.28''$
$b=24''$; $h=12''$; $A=9.4''$; $k=1.00''$
$b=24''$; $h=10''$; $A=7.5''$; $k= .90''$

After k has been found, the moment of resistance of the modified beam is obtained from the equation

$$M = \frac{f(I''+I''')}{(h'+k)} = \frac{15000(I''+I''')}{(h'+k)} \qquad (3)$$

Where $I'''=I'+Ak^2$, and $I''=\frac{1}{90}b(h'-k)^3$.

The extreme compressive stress in the concrete is

$$f'' = \frac{1}{30}\cdot\frac{15000(h'-k)}{(h'+k)} \qquad (4)$$

Likewise, since $M'' = \dfrac{f''I}{(h'+k)}$, where $I = 30I''$

$$M' = \frac{f'I'''}{(h'+k)}$$

and $f' = 30f''$

$$M'' = \frac{M'I}{30I'''} \qquad (5)$$

Which is identical with equation (1) of Case I.

CASE III. (See Fig. 2).

In this case we shall assume that the concrete cracks on the tension side, but that the crack does not extend beyond that point at which the tensile fibre stress in the concrete is just equal to its ultimate tensile strength: viz., about 200 pounds per square inch. In this case the lower portion of the sound concrete will be in tension.

Let $x =$ distance from center of beam to the point in concrete at which the tensile fibre stress is 200 pounds. The corresponding fibre stress in the beam is 6000 pounds. The exact

value of x in terms of h and k might be expressed, and likewise a second equation written, giving the value of k in terms of h and x; from which equations both k and x might be obtained. The resulting equations, however, would be very cumbrous. It will be sufficiently accurate to obtain the value of x on the supposition that the neutral axis remains in the center of the beam, and then from the result subtract about three-quarters of an inch, which is nearly the value of k.

$$\text{Hence, } x = \frac{6000}{15000} \times \frac{h}{2} - \tfrac{3}{4} = .2h - .75 \qquad (6)$$

$$k = \frac{\tfrac{1}{30}(h'+x)\,b\,[\tfrac{1}{2}(h'+x)-x]}{A + \tfrac{1}{30}b\,(h'+x)}$$

$$\text{whence } k = \frac{b\,(h'^2 - x^2)}{2\,[30A + b\,(h'+x)]} \qquad (7)$$

If $b = 24''$; $h = 15''$; $A = 12''$; $x = 3.75''$; $k = .80''$
$b = 24$; $h = 12$; $A = 9.4$; $x = 2.85$; $k = .68$
$b = 24$; $h = 10$; $A = 7.5$; $x = 2.25$; $k = .60$

The moment of resistance of the modified beam is, as before,

$$M = \frac{15000\,(I'' + I''')}{(h'+k)} \qquad (8)$$

where $I''' = I' + Ak^2$

$$I'' = \frac{b\,(h'+x)^3}{360} + \frac{b\,(h'+x)\,[\tfrac{1}{2}(h'+x)-(x+k)]^2}{30}$$

Equations (4) and (5) hold for Case III as well as for Case II.

Other cases can be solved by the same general method given above. For example, the concrete may have a greater depth than the beam.

CASE IV (See Fig. 3.)

In this case we shall assume that a square steel wire is imbedded near the lower portion of a concrete beam, and that the stress in the wire does not exceed 15,000 pounds per square inch.

Let t = length of side of steel wire.
b = breadth of concrete beam.
h = depth of concrete beam.
d = distance from center of beam to center of steel wire.
k = distance from center of concrete beam to neutral axis of the concrete-steel beam.

As before, let us consider the concrete beam as transformed into a steel strip having a breadth of one-thirtieth of its former

width. We then have to deal with a modified shape similar to the preceding cases.

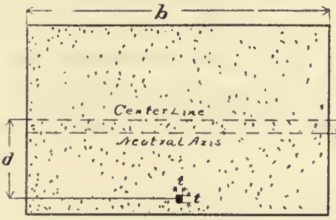


Fig. 3.

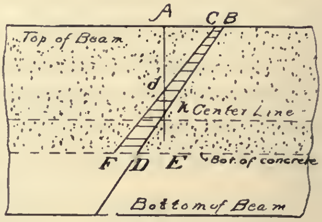


Fig. 4.

Then, $$k = \frac{t^2 d}{\frac{1}{30}bh + t^2} \tag{9}$$

Let $I'' =$ moment of inertia of concrete strip about the new neutral axis.

Let $I''' =$ moment of inertia of steel wire about the new neutral axis.

Then, $$M = \frac{f(I''+I''')}{(d-k)} = \frac{15000(I''+I''')}{(d-k)} \tag{10}$$

where $$I'' = \frac{bh^3}{360} + \frac{bhk^2}{30}$$

$$I''' = t^2(d-k)^2.$$

The maximum tensile fibre stress in the concrete is,

$$f' = \frac{15{,}000(h'-k)}{30(d-k)} \tag{11}$$

where $h' = \frac{1}{2}h$.

The maximum compressive fibre stress is,

$$f' = \frac{15{,}000\,(h'+k)}{30\,(d-k)} \tag{12}$$

Equations (10), (11), and (12), are readily adapted to any other stress in the wire than 15,000, by making the proper substitution. The one condition is that the stress shall not exceed the elastic limit of steel.

It is evident that other cases might be solved by the method here outlined but it is believed that these few cases sufficiently illustrate the method.

That the strength of a beam is greatly increased by imbedding it in concrete is readily seen by solving Case I for one or two conditions. Thus suppose $b = 24''$; $h = 15''$; $A = 12.0''$; $I' = 424$. Then from Eq. (1);

$$M'' = \frac{6750}{12720} M'.$$

That is, the moment of resistance of the concrete is more than one-half of that of the steel beam, and the strength of the beam is therefore increased fifty per cent. by the addition of the concrete.

Again, let us take the case of a concrete beam having a wire imbedded one inch from its lower edge.

Let $b = 6''$; $h = 12''$; $d = 5''$; $t = .5''$.

From Eq. (9), $k = \frac{1}{2}''$.

$I'' = 30$; $I''' = 5$.

$M' = \frac{5}{30} M''$.

In this case the strength of the concrete beam is increased one-sixth by the presence of the steel wire, although the area of the wire is but four-tenths of one per cent. of the total area of the beam.

If the width of concrete is great enough, the concrete will bend about its own neutral axis, rather than that of the combined concrete-steel beam. The adhesion between the concrete and steel should be sufficient to prevent such independent rotation.

In the case of the wire imbedded in the concrete beam, if the adhesion between the materials is destroyed, the stress in the wire at once reduces to zero and the concrete beam carries the entire load. For this case, then, the adhesion between the wire and concrete must be equal to the total maximum stress which can occur in the wire. Practically, the stresses in the wire should be computed for adjacent sections near the end of the beam and the adhesion between the two materials for the length included between the sections should be equal to, or greater than the difference between these stresses. It is thus seen that the procedure is similar to that for the determination of the pitch of rivets in the flanges of a plate girder.

For a beam imbedded in concrete, the case is not so simple, since each of the two materials will carry a portion of the load after adhesion between them has been destroyed. It is necessary to determine, then, what portion of the bending moment each part is capable of resisting when rotating independently about its own neutral axis. From this the fibre stress in the concrete may be obtained and the strain line CF, Fig. IV. can be drawn.

From the formulæ given above the fibre stress in the concrete, where the two materials act as one beam, may be determined, and the strain line BD drawn for this condition. In the figure, k is the position of the neutral axis of the combined beam, and d the neutral axis of the concrete when acting alone. The depth of the concrete is AE. Then the effect of the adhesion is to change the stress in each fibre of the concrete from an amount proportional to the abscissas of the line CdF, to an amount proportional to the abscissas of the line BkD. The shaded area CBDF represents the amount of constraint caused by the adhesion. The area of the shaded portion, multiplied by the breadth of the beam, is equal to the total amount of adhesion, between the section and the end of the beam.

Consider two sections near the end of the beam. Determine the shaded area for each section. Then the difference in area of the two shaded portions included between similar horizontal lines, multiplied by the breadth of the beam, is equal to the amount of adhesion required for that part of the beam bounded by the two sections and the two horizontal layers. Thus any part of the beam may be tested.

In the above discussion the concrete was assumed to have a coefficient of elasticity of one million, and to otherwise act as an elastic material. It must be remembered, however, that cement is not a uniform product, such as steel or iron, but that it may vary in quality from utter worthlessness to that of the best cements upon the market. The elastic properties vary correspondingly, and hence actual tests may frequently give results widely different from those of this article. The writer hopes to conduct, in the near future, a series of tests, to determine experimentally the elastic behavior of cements and concretes under different conditions.

The writer is indebted to Mr. Frank B. Walker, '97, for the sketches accompanying this article.

CORN OIL.

BY HARRY W. ALLEN.

The investigation of the physical and chemical properties of corn oil, discussed in this article, was undertaken with the purpose of finding some economical use for which the oil might be adapted, either in its natural condition or after some cheap method of treatment. The oil is obtained from the refuse of corn distilleries, and from corn before it is employed in the manufacture of starch. Enormous amounts are now wasted which could be obtained at a nominal expense if some practical use for the product were known. The only manner in which the oil at present is utilized to any extent, is as an adulterant. Being much cheaper than linseed oil, it is used with the latter for mixing paints, and in the adulteration of lard it has been substituted for cotton-seed oil. Corn oil has been employed for burning, as a lubricant, and in soap-making, but for none of these uses does it seem specially applicable.

The experiments with the oil from this economical standpoint were rendered difficult from the beginning of the work by a scarcity of literature on the subject. No thorough examination of the oil seems ever to have been made, and only short references as to its general appearance, specific gravity, etc., are to be found. The latest works on the subject of oils contain a few generalizations in regard to its physical and chemical characteristics, but nothing as to its chemical composition. This lack of foundation for the work compelled first a systematic examination of the oil, and for this reason the efforts to find some practical use for the oil have not been completed.

When the oil is obtained from the residue of the fermentation vats, it is of a reddish brown color. The samples used in these experiments were evidently prepared by the second method, for the oil possessed a golden-yellow or straw color. The odor is very peculiar, smelling somewhat like a mixture of corn and beeswax, and is very sweet. Heated to a high temperature the oil smells like burnt lard, and under ordinary pres-

sure cannot be distilled without decomposition. Its specific gravity at 15° C. is .9233.

The oil is extremely soluble in ether and benzol, but is very slightly affected by cold alcohol. According to Smith,[1] absolute alcohol at 16° C. dissolves two parts in 100; at 63° C., 13 parts in 100. In commercial acetone at 16° C. it dissolves 24 parts in 100, and at 16° and 63° C. it is soluble in glacial acetic acid 3 and 9 parts in 100.

Small quantities of the oil treated with various reagents of different strengths gave the following color tests, which, however, do not seem to be very distinctive:

Reagent.	Result.	Reagent.	Result.
NaOH 1.34	Dirty, yellowish white.	HNO_3 1.33	Light brown, with yellow tint after heating.
H_2SO_4 1.475	No action until heated. Brownish-red, with traces of dark purple. On further heating decomposed with fumes, leaving a black, sticky mass.	HNO_3 Con.	Without heat same color as above.
		$H_2SO_4 + HNO_3$	Light brown color.
		Aqua Regia	Slightly yellow.
H_2SO_4 1.635	No action until heated. Brown color, about same as preceding, with similar traces of purple.	+ NaOH 1.34	First a light yellow. More NaOH—light brown, resembling orange. Fibrous.
H_2SO_4 Con.	Reaction without heat. Yellowish-brown. Heat changed this color to preceding brown.	HNO_3 1.33	Light brown.
HNO_3 1.18	Slightly yellow with a brownish tint after application of heat.	+ NaOH 1.34	Fibrous, light yellow.

A column of the oil examined through the spectroscope showed a marked absorption of the violet end of the spectrum beyond the line "8." In a polariscope with a 20 c. m. tube, the oil was found to have a dextro-rotatory power of 2.05°.

The oil is readily saponified by means of caustic soda or potash. It was found more expedient to use alkali of only moderate strength in order to thoroughly saponify the oil, as sodium hydroxide 1.34, at first employed, seemed to produce an unsaponifiable oil, which was changed into a sodium salt only after constant mixture with the alkali. An odor peculiar to "Johnny-cake" is very noticeable upon heating the oil with the sodium hydroxide. The sodium salt is a yellow, corn-colored soap readily soluble in water and hot alcohol, but not in ether to any extent. It would not crystallize out of alcohol,

[1] Jour. Soc. Chem. Ind., 1892, p. 505.

but was precipitated when cold as an amorphous mass. All efforts to get a good crystallized salt of the oil were without success, the barium, lead, and magnesium salts, also being almost structureless in appearance.

The free acids of the oil were readily obtained from the aqueous solution of the sodium salt as a yellowish colored oil, somewhat lighter in shade than the original corn oil, and having a specific gravity of .909. These acids are readily soluble in ether, almost insoluble in hot and cold alcohol, and not in the least soluble in water. The last fact is corroborated by the quantitative results obtained. According to these facts, the corn oil yields about 97% of its weight as free acids, which corresponds very closely to the Hehner value—the per cent. of insoluble fatty acids—accorded to the oil by numerous chemists. The acids solidified at about 14° C., becoming thick and jelly-like, and again became fluid at from 16–17° C. The oil cannot be distilled at ordinary pressure, but breaks down, partially at least, into acrolein, as it evidenced by the peculiar odor. The free acids were also separated from the corn oil directly, without conversion into the sodium or potassium salt, by passing a current of super-heated steam through the oil. From the different characteristics of the acids it is almost certain that the greatest proportion of the mixture is oleic acid, with a greater or less amount of oxy-oleic acid, depending upon the sample of oil taken.

The determination of the iodine absorption of the corn oil and the free fatty acids gave most surprising results. The corn oil gave iodine values from 129-131%, and the free acids a value from 114-115%. These large iodine values would place the corn oil in the class of drying oils, which is not in accordance with its other qualities. It does not dry readily and the ordinary process of "boiling" and the addition of lead oxide have but little effect upon it. It has been observed, however, that certain drying properties are imparted to it if heated in a current of air at 150° C., with the subsequent addition of manganese borate. It was with the view to convert the oil into a better "dryer" either by a reduction or oxidation of the fatty acids contained, that most of the experiments with the oil were planned. These investigations have not yet been finished, but have developed a number of interesting facts in regard to the oil.

The result of the oxidation of the oil was one of the best proofs obtained that oleic acid is a constituent. One method

adopted for the purpose was to simply pass a current of dried air through the oil at a temperature of 200-260° C. for a number of hours. The oil became heavier, having a specific gravity of .96, and changed its color to a reddish shade, resembling that of "golden oil." It was thick and viscid and in odor resembled hot lard. The sodium salt from this oil also had a reddish color and differed from the soap from the original corn oil in that it was readily soluble in hot sodium or potassium hydroxides. The free acid from this salt was a reddish-yellow oil, thick and jelly-like up to 17° C. Its specific gravity at 30° was .93. Unlike the original acids from the corn oil, it was readily soluble in cold alcohol. From its general behavior and characteristics, it was undoubtedly oxy-oleic acid.

The reduction of the oil by means of metallic magnesium in a digester, under high pressure and temperature, was not successful in changing the composition of the fatty acids but resulted in a very good magnesium salt of these acids. The salt was fairly well crystallized, of a yellowish-white color, and was obtained after heating the oil with magnesium powder to 206° C. and a pressure of 20 atmospheres. This salt was insoluble in alcohol and water but readily so in ether. At a temperature of about 100° C., it conglutinated but did not melt. This presumably was magnesium oleate, and the method for its preparation seems to be an entirely new one, according to any literature on the subject which has been available.

LATITUDE.

BY PROFESSOR WILLIAM R. HOAG.

[By altitudes of the sun near the meridian, employing a graphical chart for increasing the accuracy.]

In the determination of terrestrial latitude the instruments, methods and plans of reduction employed are as varied as the demands placed upon such knowledge; the choice being governed largely by the degree of accuracy required. In exploration and reconnaissance, the nearest five minutes of arc frequently being sufficient, we find the pocket sextant well suited to such needs. A single observation on the sun or star at meridian passage with no correction for refraction will give the desired accuracy. For purposes of navigation and for use with the solar compass the latitude is gained within about a minute using the telescopic sextant on ship-board and the engineer's transit or solar compass on land.

In geodetic work as the inauguration of a system of triangulation, or the establishment of a boundary line between two countries the highest accuracy is desirable, and the nearest tenth of a second is secured by the zenith telescope, employing a large number of observations together with an elaborate plan of reduction.

The Civil Engineer is sometimes called upon, in taking up a detached piece of topographic work or in locating certain prominent political stations for purposes of mapping, to establish latitude within 5 or 10 seconds.

A small zenith telescope, with the Talcott method of observing, will enable the engineer to secure this accuracy. This instrument is rarely accessible and its cost, $300, forbids its addition to his instrumental outfit. It is proposed in the following article to show how the engineer, with his ordinary transit, can easily establish his latitude within 10 seconds and with the aid of a sextant, a comparatively common instrument costing about $75, he can determine it within 3 to 5 seconds.

The scheme in a somewhat less elaborated form is substantially what we developed several years ago and have since used with the classes in Geodesy and in the practical work of the State Topographical Survey, securing a degree of accuracy in most cases within the limits named above. The basis of accuracy in all physical measurements is repetition. When the function to be determined is constant, as a geodetic angle or the length of a standard bar, with the determining observations all made under equally favorable conditions, the simple arithmetic mean of all, *i. e.* the average, is the best value which can be given to the function based upon such observations. When we have a uniformly varying function, as the rod intercept for different distances from the transit, in stadia work, or velocity of water corresponding to varying angular velocity of the current meter exposed to its action, we can readily determine the equation between the two dependent variables by plotting the one along the axis of X and the second along the Y axis. These plotted observations will give a series of points agreeing with a straight line in so far as the observations are perfect, and a straight line adjusted to agree most nearly with all, giving to each its due weight, determines the relation sought.

In case the equation between the two variables is above the first degree, the plotted points give a curved line and we can no longer employ the usual methods for obtaining graphically a mean value of the function.

A glance at the conditions involved in our problem shows that we have this last form of relation present, and to avail ourselves of the desirable feature of multiple observations we must devise a plan to treat these observations giving a curved locus, after the manner of the right line with the simple direct variables or the arithmetic mean in case the desired constant is capable of direct measurement.

Figure 1 represents the sun at meridian passage or at apparent noon. By observing the altitude of the sun at this time and subtracting from it the sun's declination we readily obtain the co-latitude and hence the latitude of the place.

The usual plan of observation with this method is to follow the sun in altitude with the instrument to its highest point and accept this one determination as its altitude at meridian passage and from this deduce the latitude.

This method is not only wrong in theory, since the sun is not at its maximum altitude at meridian passage, owing to its

change in declination, but it violates the fundamental principle touching repetition of observations in permitting but one observation to be taken.

Now, if instead of idly watching the sun in its change of altitude during the ten or fifteen minutes preceding its passage and about an equal time after, to make sure that it has passed, let the observer make independent observations for altitude as frequently as careful work will permit, noting the watch time of each observation. With the sextant the interval need not be greater than one minute of time and not more than two and a half minutes when the transit is used. This extra time

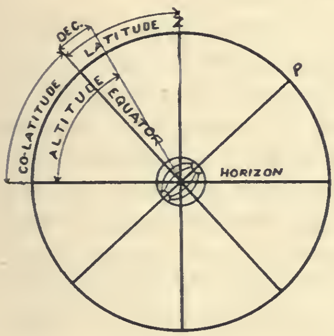


FIGURE 1.

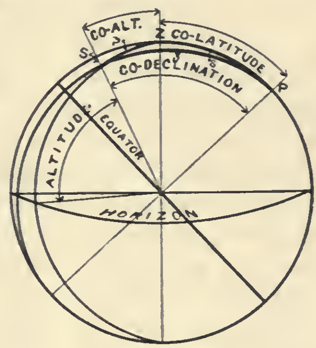


FIGURE 3.

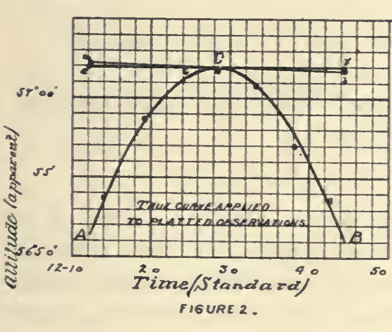


FIGURE 2.

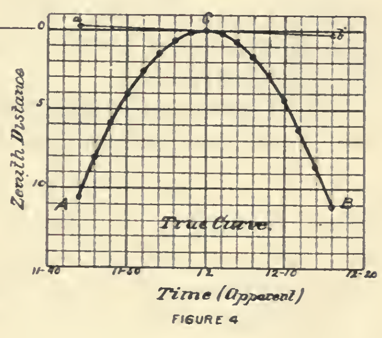


FIGURE 4

is required in using the transit in the direct and reversed position to eliminate instrumental errors.

When accuracy exceeding five seconds of arc in latitude is desired the sextant must be employed on two or three successive days, observing on alternate limbs of the sun each day to eliminate personal error of contact.

Of course when this degree of accuracy is desired the sextant

must be in precise adjustment, with its index and eccentricity errors accurately known, and the refraction errors of its shade glasses equally well determined, should these be used instead of the eye-piece shade.

We now plot these observations for altitude using the mean of each direct and reverse measure with the transit as one observation, laying off time on the axis of X, and altitude as Y ordinates.

Figure 2 exhibits, according to this plan, the observations taken at Pipestone, August 20, 1895, with a Troughton & Simms transit reading to ten seconds. Each plotted observation is the mean of a direct and reverse observation.

Now if we had a curve plotted to the same scale representing the true altitude of the sun during the whole time covered by these observations, by applying it to the observation curve we have the same ability to determine its true position relative to the plotted observations as in the case of the straight line. The adjusted position of the true curve shows the true altitude of the sun during the time covered by the observations as a function of latitude and reading it for the instant of noon shown by the central Y axis of the curve we have the altitude and from it the latitude desired. We will now develope a plan for easily constructing this true curve.

Figure 3 shows the spherical triangle involved, *SPZ*, in which we wish to study the changes coming to *ZS* consequent upon changes to α (the hour angle), and *SP*, the co-declination, with *ZP* a constant.

The fundamental equation involving these parts written out for this spherical triangle becomes,

$$\cos.p = \cos.z \cos.s + \sin.z \sin.s \cos.\ \alpha$$

By substituting in this formula the s and different values of α and the corresponding values of z covering the desired time before and after noon we can determine p for the several values of α which passing to the co-functions enables us to construct the true curve.

This method, however, is seen at once to be laborious requiring the use of an equation not adapted to logarithmic computation and further by requiring the determination of the full function a 7-place table must be used and must be entered nine times for each substitution or about fifty times in all in determining nine points of the curve.

To construct this curve we do not need the whole function v, but only the changes coming to it. Hence if we differentiate the equation above with respect to p and α regarding z and s as constants, the latter is such as has been noted and z can be regarded so for the present since the maximum change which can come to it is less than 15 seconds, we shall obtain the relative change between these variables which we desire. Even the 15 seconds will not remain an outstanding error since in platting the final curve we shall employ oblique axes to take account of this declination change.

Differentiating equation (1) gives

$$-\sin.p\, dp = -\sin.z \sin.s \sin.\alpha\, d\alpha \tag{2}$$

or
$$\frac{dp}{d\alpha} = \frac{\sin.z \sin.s \sin.\alpha}{\sin.p} \tag{3}$$

Equation (3) expresses the rate at which p is changing relative to α for any given value of α and p. Calling this curve a circular arc which it is sensibly within the limits we use, *i. e.*, four degrees from the center, we can make this equation express the full change coming to p for a given $d\alpha$ by writing the equation for $\frac{\alpha}{2}$ instead of α since at the middle point of the arc, the curve being circular, the ratio change between dp and $d\alpha$ is the half of what it is at α or for this point p and α are having their mean relative change.

A rigid substitution in Eq. (3) would of course require that p corresponding to each α be used. To call p uniformily ZS can introduce as a maximum error to p about 4 seconds of arc. This occurs only near the outer limits of the curve, and if thought necessary even this can be eliminated.

Equation (5) for our use then becomes

$$dp = \sin.z \frac{\sin.s \sin.\frac{1}{2}\alpha}{\sin.p} d\alpha \tag{4}$$

an equation adapted to logarithenic computation and dealing with the correction only.

To make one substitution in this formula requires the use of the table six times. If we desire nine points in the curve, by allowing for no declination change, except in the plotting, the curve as computed is symmetrical, hence the vertex point and four on one side will give the whole curve. The vertex point falls on the axis of X since it is for $\alpha = 0$. This reduces the needed substitutions to four and as z, s and p remain constant

throughout the four, the additional substitutions require but three logarithms each. This gives our curve complete with nine points fixed by using the table but fifteen times. One case of such reductions will show how this work can be further reduced one-half.

Let it be required to determine the true curve for the 24th of August, 1895, in latitude 43° 58′—declination on that date being 10°56′ north.

This is the date on which the observations were taken at Pipestone platted in Fig. 2.

We then have $z = 79°.04'$, $s = 46°.01'$, $p = z - s = 33°.03'$ and we assume for $\propto$ the successive values of 1°, 2°, 3° and 4° and $d\propto$—letting the minute be the unit—will equal 60, 120, 180 and 240.

This substitution is best followed by the following tabular form:

Log. sin. 79°04′	9.992044
Log. sin. 46°01′	9.856934
Log. sin. (a.c.) 33°03′	0.263308
	0.112286(c)

½∝ log. sin. (a)	d ∝	log. (b)	(a)+(b)+(c)	Minutes	Seconds
30′ 7.940842	60	1.778151	9.831279	.6781	40.68
1° 8.241855	120	2.079181	0.433322	2.712	162.72
1°30′ 8.417919	180	2.255273	0.785478	6.101	366.11
2° 8.542819	240	2.380211	1.035316	10.847	650.62

We notice that these values are very nearly proportional to 1, 4, 9, 16, showing the curve to be closely parabolic. This gives the second order differences uniform and enables us to readily interpolate eight additional points on the curve, making 17 in all. Thus:

10.2	10.2	
40.7	30.5	20.3
91.5	50.8	20.3
162.7	71.2	20.4
254.2	91.5	20.4
366.1	111.9	20.3
498.3	132.2	20.3
650.9	152.5	

Thus one substitution requiring the use of the table six times readily gives us seventeen points on the curve, quite sufficient for the most exact construction.

The following table has been made using equation (4) and

checked at intervals with (1) and gives this value of dp for $\alpha = 1°$ for 10° of north latitude, *i. e.*, from 40° to 50° and the full range of the sun's declination.

TABLE

Showing the difference between the altitude of the sun at apparent noon and at four minutes before or after noon, neglecting declination change.

LATITUDE.

N'th Decli-nat'n	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°
25	84.2	77.8	72.1	67.1	62.7	58.8	55.2	51.8	48.6	45.7	43.2
20	66.0	62.1	58.5	55.2	52.1	49.1	46.7	44.4	42.2	40.1	38.0
15	54.5	51.8	49.3	46.9	44.7	42.6	40.8	39.1	37.4	35.7	34.1
10	47.3	45.2	43.3	41.5	39.7	38.1	36.5	35.1	33.7	32.3	30.9
5	41.8	40.1	38.6	37.1	35.7	34.4	33.0	31.7	30.6	29.5	28.4
0	37.4	36.1	34.9	33.7	32.6	31.5	30.4	29.3	28.3	27.3	26.3
So'th											
5	33.9	32.7	31.6	30.7	29.8	28.9	27.9	27.0	26.1	25.3	24.5
10	30.9	29.9	29.0	28.2	27.4	26.7	25.8	25.0	24.2	23.5	22.9
15	28.3	27.5	26.8	26.1	25.4	24.8	24.1	23.4	22.7	22.1	21.5
20	26.0	25.3	24.7	24.1	23.5	23.0	22.4	21.8	21.2	20.7	20.2
25	24.0	23.4	22.8	22.3	21.8	21.4	20.8	20.3	19.8	19.4	19.0

The value taken from the table for the latitude of the place and the declination of the sun and multiplied by the following numbers—¼, 1, 2¼, 4, 6¼, 9, 12¼ and 16 gives the ordinates of the true curve. Entering the table for the case which has been analytically determined above—Lat 43° 59′, Dec. 10° 56—gives 40.66. Using the multipliers ¼, 1, 2¼, etc., gives for the ordinates of the curve 10.2, 40.7, 91.5, 162.6, 254.1, 366.0, 498.2, 650.6. This shows a sufficiently close agreement.

For the sun near the meridian we can call the change in declination so much change in altitude and apply it with the proper sign to the quantities above. Thus on the date of our observations the sun was passing south at the rate of 52″ per hour or 1.7″ per each 2 minutes of time to which our ordinates above correspond.

This gives the following corrections: 1.7, 3.4, 5.2, 6.9, 8.6, 10.4, 12.1, 13.9. These are to be applied with the minus sign to correct the forenoon ordinates and with the plus sign to the afternoon ordinates when they are to be laid off from the rectangular axis.

By drawing the oblique axis *ab* (Fig. 4) first, the original ordinates can be used and set off from this axis, thus using the same ordinate for equal time before and after meridian passage.

In constructing the true curve we have taken no account of differential refraction which would tend to slightly flatten the curve. In latitude 45° this error would be greatest when the sun was at the winter solstice and would then be 0.6″, and this affects only the outer portions of the curve. For all work done during the summer months this error is less than 0.2″.

Reading the plat shows the sun's apparent altitude at meridian passage to be	57° 1′54″
Refraction (corrected)	38″
True altitude	57° 1′16″
Declination	11° 1′17″
Zenith distance	45°59′59″
Latitude	44°00′01″

GROUND DETECTION ON ELECTRIC CIRCUITS.

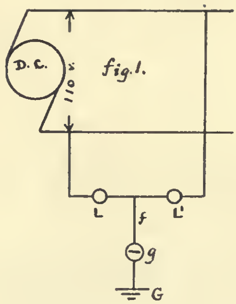
BY H. M. WHEELER, '96.

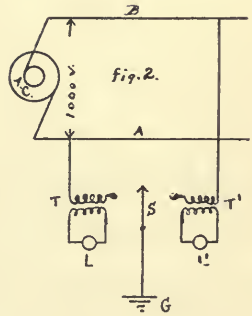
1. *Lines in General.* Grounds may often be detected by the eye. When they are caused by swinging contacts or by broken or "down" wires, a very little observation is generally sufficient to locate the faulty place; while in many cases, faults in the insulation, blackening of woodwork, and fusing of metallic conductors are all immediately patent and require no special instruments for their detection.

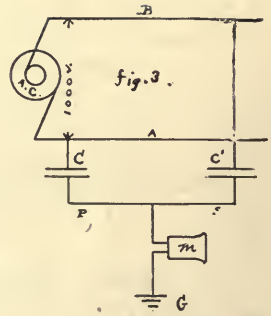
2. The most common method of detecting grounds is by the use of the magneto. This is applicable to overhead circuits; but does not give reliable results on underground circuits, submarine cables, or any circuits which contain condensers or a large amount of distributed capacity. The line to be tested must be "idle" and disconnected from all other lines and the earth. The magneto leads are connected to the line and to the earth respectively. If on turning the handle the bell rings, the insulation resistance of the line is not $>$10,000 to 25,000 ohms and the line is probably grounded. The line is now broken at the joints and the sections tested separately. Then the grounded sections are examined foot by foot until the exact spot is located. If the line is very long, distributed capacity may cause the bell to ring when there is no ground. In such a case it is well to use an ordinary electric bell, or a galvonometer, with the direct current from a battery or small dynamo, the battery and bell being in series and the test carried out as before.

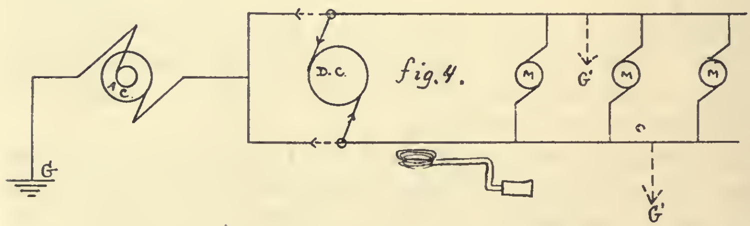
3. *Central Station Indicator for D. C. Constant Potential Circuit.*[1] The connections are shown in Fig. (1). L and L′ are two incandescent lamps of equal candle power joined in series parallel to the mains, the sum of the normal voltages of L and L′ being equal to that of the dynamo. Ggf is a ground connection through the galvanometer (or bell) g. When there is no ground on the mains, the galvanometer deflection is nil and L and L′ have equal brilliancy. When either main is

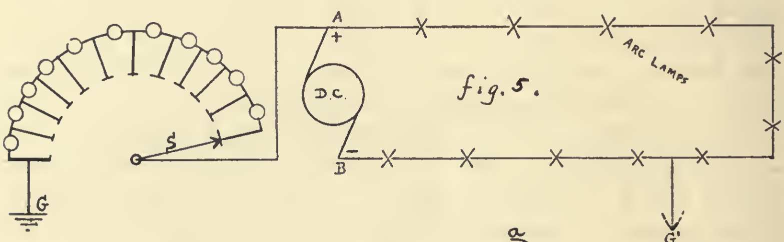
[1]Abbott: Electrical Transmission of Energy, pp. 219, 220.


D.C.
110 v.
fig.1.
L
L'
f
g
G


B
A.C.
1000 v.
fig.2.
A
T
S
T'
L
G


B
A.C.
1000 v.
fig.3.
A
C
C'
P
m
G


A.C.
G
D.C.
fig.4.
M
G'
M
M
G'


A
+
ARC LAMPS
D.C.
fig.5.
S
G
B
G'

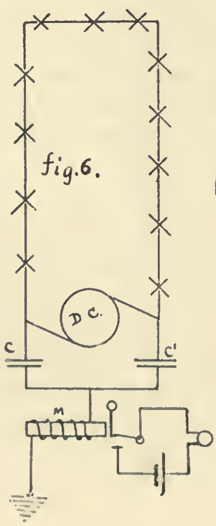
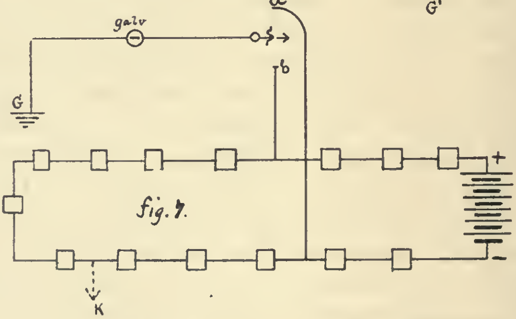
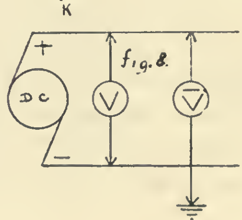
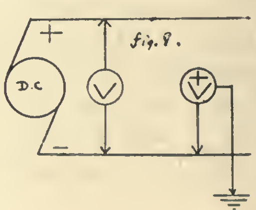


fig.6.
D.C.
C
C'
M


a
galv
s
b
G
+
fig.7.
K


+
fig.8.
D.C


+
fig.9.
D.C

grounded, the lamp on its side burns less brightly, being shunted around by the ground current, and the galvanometer needle is deflected. While this method gives continuous and automatic indication of grounds, it is objectionable from the fact that the permanent ground causes a constant and unnecessary strain on the insulation, and insures a ground current through anyone touching the line. These objections are obviated by using a switch at *f* and testing at stated intervals.

4. *Central Station Indicator for A. C. Constant Potential Circuits.*[1] In Fig. (2) the transformers T and T′ have one end of their primary coils connected to the mains A and B respectively, while the other ends can be grounded through the switch S. Across the secondary coils are the lamps L and L′. If on grounding T, there is a ground on B, the ground current through the transformer will render L incandescent. A ground on A is indicated when, upon grounding T′, L′ becomes bright.

5. A still better method which gives continuous and automatic indication of grounds is shown in Fig. (3).

C and C′ are small condensors, M is a telephone receiver (or an electric bell with polarized coil) When either main is grounded the telephone sets up a continuous hum. If on breaking the circuit at S the hum still continues, A is grounded. In the same way break circuit at P to test B.

6. *Mr. E. M. Bentley's Ground Detector for Electric Railway and Power Circuits.*[2] In Fig. (4), full line switches show ordinary series double metallic power circuit. Move switches to dotted position and send a pulsating or alternating current through the mains (now in parallel) and the ground GG′. Carry a coil attached to a telephone receiver along the line and notice the humming. At grounded points G′, the humming suddenly ceases owing to the disappearance of the current into the earth. Hence grounds are easily located by this method. The coil and telephone arrangement may be used in locating grounds in regular alternating circuits or in tracing the same where the wires are behind the plastering or under the floors as in a house.

7. *Mr. M. D. Law's Method of Locating Grounds on Arc Circuits,*[3] Fig. (5). At the left is a bank of incandescent lamps, in series, with one terminal grounded. The lamps are taken of such

[1] Ibid, pp. 220, 221.

[2] *Electrical World*, XIII; p. 214.

[3] *Electrical World*, XIX; p. 160.

voltage as to be a multiple of the average drop between contiguous arc lamps, while their total resistance is such that all just come up to normal candle power when connected directly across the mains. To test for grounds make connection as shown and move the arm S till the grounded lamps just come up to candle power. Next disconnect S from A and join to — terminal B and move S as before. If the sum of the lamps brought up to candle power in the two tests equals total number of lamps in bank, the arc circuit is "dead" grounded at a point G′ distant from A such that

$$\frac{G'A}{G'B} = \frac{\text{no. lamps lighted in first test}}{\text{no. lamps lighted in second test}}$$

If the sum of the lamps lighted in the two tests does not equal total number in the bank, the ground is only partial; but the above proportion is still approximately true.

A modification and improvement upon this method has been made by Mr. E. E. Stark.[1]

8. *The Rudd Automatic Ground Alarm for Arc Light Stations*,[2] Fig. (6). Two condensers, C and C′, are joined across the mains with a common ground connection through the magnet coil M. For normal conditions on the arc circuit no current passes through M and the coil is neutral; but when a ground occurs, the sudden change in voltage sends a momentary pulsating current through M. This energizes the coil which attracts a trigger, thus loosening a shutter S, which falls and completes a second circuit consisting of a bell and one cell. The bell rings and continues till the attendant breaks its circuit. The ground may now be located by Mr. Law's method or by the bridge method exploited by the Western Electric Company, Chicago, who manufacture the ground alarm.

9. *Ground Detection on the Minneapolis Fire Alarm System*, Fig. (7).[3] The alarm boxes are in series with the battery as shown. When there is no ground the galvanometer shows no deflection if the switch s is moved to a or b. If there is a ground at k, the galvanometer will be deflected when the switch is in contact with b or a, and the corresponding deflections will be proportional to the distances k+ and k—. Hence we have a rough method of determining where the ground is.

[1] *Electrical Engineer*, vol. XIV, p. 25.

[2] *Electrical World*, vol. XIV, p. 131.

[3] In Fig. (7), test wires *a* and *b* should be directly across terminals of battery.

10. Since the freedom of any circuit from grounds depends primarily upon the insulation, an easy method of detecting a ground, or leak, is to measure the insulation resistance of the line in question. If this insulation resistance is found to be some high figure, depending upon the requirements of the case, the line is considered all right; a certain minimum insulation resistance being deemed sufficient. The ground is "partial" below this limit, and becomes "dead" when the insulation resistance equals zero. The following methods deal with the detection of grounds through measurement of insulation resistance.

11. *The Voltmeter or "Drop" Method.*[1] This method may be used to measure the insulation resistance of a line to the earth, of armature or field coils to the frame or, in fact, of any conductor to another; it requires, however, for its operation, a direct current. A voltmeter of known resistance R is connected across the dynamo terminals (Fig. 8), and the voltage V is noted; next the — lead of the voltmeter is grounded and the reading ^-V is noted.

Since the same current passes through the voltmeter and the ground

$$C = \frac{^-V}{R} = \frac{V - {^-V}}{^-R}$$, where ^-R is the insulation resistance of the — side.

$$\text{Whence, } {^-R} = \frac{V - {^-V}}{^-V} R$$

In the same way (Fig. 9) the resistance of the + side is found, and $^+R = \frac{V - {^+V}}{^+V} R$.

For a voltmeter of R = 20,000 ohms, a 110 volt circuit, and the voltmeter readable to 1/10 volt, no deflection means that

$$^{\pm}R > \frac{110 - .1}{.1} 20{,}000 \text{ or } 21{,}980{,}000 \text{ ohms.}$$

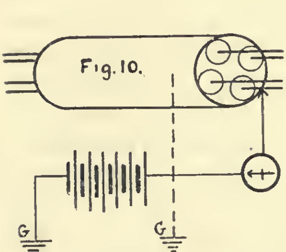
In the same way values of $^{\pm}R$ may be calculated for different values of $^{\pm}V$ and the results may be written in megohms opposite their corresponding scale readings. Of course, in further tests, the voltage V must be that on which the table was based.

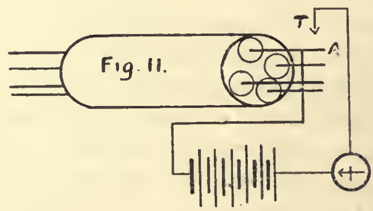
12. *The Insulation Resistance of Storage Batteries.*[2] Suppose three storage cells in series to be grounded at A_1, A_2, A_3, etc. Connect any point A through a sensitive

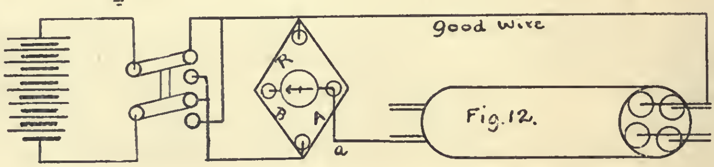
[1] *Electrical Engineer*, Vol. X, p. 687.

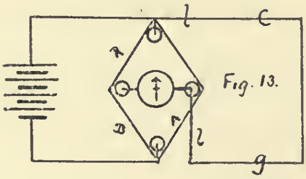
[2] *London Electrician*, XXXV, p. 855.

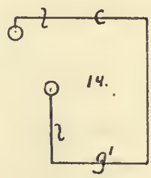
high resistance galvanometer in series with an ammeter to the earth, choosing A such that there is a large readable deflection

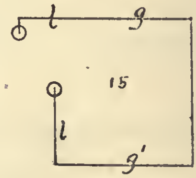


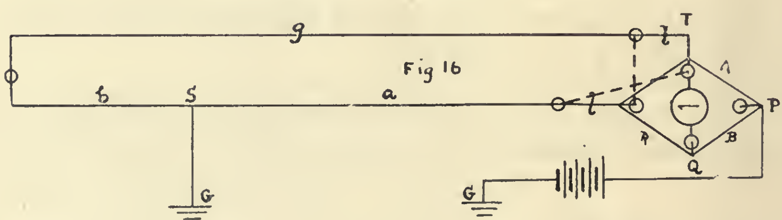


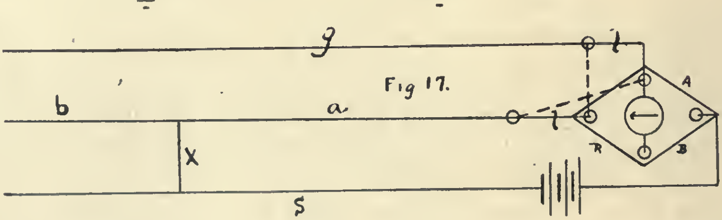












of the needle. Now add resistance in series to the galvanometer till the deflection is reduced to one-half its first value. If c = current for a galvanometer and ammeter resistance g, and c′ is

current in the second case for a total resistance g'; then the total insulation resistance of the battery is

$$R = \frac{c\,g - c'g'}{c' - c}.$$

For proof of this see original article. This method may also be used for measuring the total insulation resistance of a complicated network, such as a three or five wire system.

13. For those desirous of further information on the subject of insulation resistance, reference may be made to: Maj. Cardew's method of using the electrometer,[1] Mr. Carl Hering's[2] description of methods of testing wire cables before leaving the factory; The U. S. Government tests[3] and others.[4]

14. *To Identify Cables at Any Point in a Conduit.*[5] Ground the desired cables at one end, disconnect and keep insulated from each other all other terminals at both ends of the conduit. With a sharp needle point, connected to a galvanometer which is grounded through a battery, make connections successively with the cables at the required point by piercing the insulation. The cables which cause a deflection of the galvanometer when so touched, are those required, provided the cables were not already "grounded or crossed." To determine which cable in a conduit is grounded[6], make connections as in Fig. (10), the circuits being open at both ends. Ground the galvanometer through a battery as shown and touch its other terminals to the various cable ends. When the terminals of the grounded cables are touched, the needle will be deflected. In case two or more cables are "crossed,"[7] connect as in Fig. (11). Detach A join to T. If A is crossed with any other cable the needle will be deflected, if not mark A and try another. Those cables which cause deflections are crossed.

15. To identify the terminals of a cable when several of the cables in the conduit may be grounded—method of H. W. Fisher.[8] In Fig. (12) a and b are any two cable terminals at opposite ends, the rest of the terminals being open. A good wire whose terminals are known is connected as shown. Balance R on the

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[1] *Electrical World*, Vol. XIX, p. 197.
[2] *Electrical World*, Vol. XVII, p. 188.
[3] *Electrical Review*, Vol. XXIV, p. 126.
[4] H. W. Fisher, *Electrical World*, Vol. XVII, p. 482.
[5] *Electrical World*, Vol. XVII, p. 481. [6] Ibid. [7] Ibid.
[8] *Electrical World*, Vol. XVIII, p. 6.

bridge till the galvanometer deflection is 0 and then reverse battery switch. If there is still no deflection, a and b are terminals of the same cable. If not b is disconnected and replaced by another terminal and the same thing tried again. This method is fairly accurate.

16. To locate the "ground" in a cable;[1] where two good wires whose terminals end near those of the cable are accessable—this being a very accurate method. The instruments necessary are: A Wheatstone Bridge, Thomson Reflecting Galvanometer, battery and two lead wires of equal resistance.

1st. Measure carefully the resistance of the lead wires.

2nd. Measure carefully the resistances in series as shown in Figs. (13), (14), (15).

Let Res. of Fig. (13) be K. $l=$ resistance of one lead wire.
Let Res. of Fig. (14) be K′ [$c=$ resistance of the cable C].
Let Res. of Fig. (15) be K″ $g=$ resistance of first good wire.
$g'=$ resistance of 2nd good wire.

$$\text{Then } c=\frac{K+K'-K''-2l}{2}$$

3rd. Make connections as in Fig. (16), where B and A are bridge arms; g is first good wire, C is grounded at S, a and b being the respective resistances of the parts of the cable on either side of S.

It is now evident that we have a bridge PQST such that for no deflection QS : PQ = TS : PT, substituting values from the figure,

$$(a+l+R):B=(b+g+l):A,\ \text{but } c=b+a,$$
$$\therefore\ (a+l+R):B=(c-a+g+l):A,$$
$$\text{and } a=\frac{B(c+g+l)-Ba}{A}-l-R$$
$$=\frac{B(c+g+l)-A(l+R)}{A}-\frac{Ba}{A}$$
$$=\frac{B(c+g+l)-A(l+R)}{A+B}$$

but from Fig. (13), $K=c+g+2l$,

$$\therefore\ a=\frac{B(K-l)-A(l+R)}{A+B},$$ of which all quantities are now known. If $D=$ length of cable C, then $\frac{a}{c}D$ is the distance which the ground S is from the measuring end.

[1]Ibid.

To check this value of *a*, reverse the leads l, as shown by dotted lines (Fig. 16), when for no deflection, as before,

$$QS : PQ = TS : PT, \text{ or } (R'+l+g+b) : B = (a+l) : A$$

$$a+l = \frac{A(R'+l+g+b)}{B}, \quad b = c - a$$

$$a = \frac{A(R'+c+g+l) - Aa - Bl}{B}$$

$$= \frac{A(R'+c+g+l) - Bl}{A+B},$$

$$\text{but } K = c+g+2l$$

$$\therefore \quad a = \frac{A(R'+K-l) - Bl}{A+B}$$

These values of *a* should check very closely.

The author gives also the method of procedure where only one good wire, or no wire at all, is accessible; also where the cable is composed of two spliced cables of different diameters.[1]

17. *Determination of the Terminals of Crossed Wires.*[2] Given two crossed wires in the same conduit and one good wire whose terminals are known.

Let 1 and 2 be crossed wires' terminals at testing end.

Let 3 and 4 be crossed wires' terminals at other end.

Let 5 and 5 be good wire's terminals at ends.

At testing end join bridge leads to 5 and 1; at other end join 5 and 3, find Res. $= R'$.

At testing end join bridge leads to 5 and 1; at other end join 5 and 4, find Res. $= R''$.

At testing end join bridge leads to 5 and 2; at other end join 5 and 4, find Res. $= R'''$.

At testing end join bridge leads to 5 and 2; at other end join 5 and 3, find Res. $= R''''$.

If $R' + R''' < R'' + R''''$ then 1 and 3, 2 and 4 belong to same wire.

If $R' + R''' > R'' + R''''$ then 1 and 4, 2 and 3 belong to same wire.

If the resistance of the cross is constant it = ½ the difference between $R' + R'''$ and $R'' + R''''$.

18. *To Locate the Cross.*[3] The same instruments are required as is § 16, also two good wires whose terminals are near

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[1] *Electrical World*, XVIII, pp. 6, 30.

[2] *Electrical World*, Vol. XVIII, p. 30.

[3] *Electrical World*, Vol. XVIII, p. 30.

the crossed wires. 1st. Find the exact resistance of one of the crossed wires as in Figs. (13), (14), (15), §16. Next make connections as in Fig. (17), where $a + b =$ Res. of crossed wire which we have just found. S is second wire crossed with it at X. ll are lead wires of known resistance. $g =$ good wire.

Then, as before,

$$a = \frac{B\,(c+g+l) - A\,(l+R)}{A+B} = \frac{B\,(K-l) - (l+R)}{A+B}$$

and on reversing leads as shown by dotted lines

$$a = \frac{A\,(c+g+l+R') - Bl}{A+B} = \frac{A(R' + K - l) - Bl}{A+B}$$

Hence the Res. to the cross from testing end is found and the distance $= \frac{a}{c}\,D$.

The author gives further methods for location of crosses, but this is the most accurate.

RAILWAY MECHANICAL ENGINEERING.

BY PROFESSOR H. WADE HIBBARD,

Member of American Railway Master Mechanics Association.

What man of mechanical tastes has forgotten the awe which a locomotive used to impress upon his boyish heart? He would go as near as he dared to the wonderful engine, gaze at the engineer as if at a higher being, admire the unconcerned manner with which he started the ponderous machinery, and when an express train thundered past the otherwise quiet village home he felt the thought that, if only it were possible, the summit of his ambition would be to become such an engineer. This feeling of the lad is perhaps but the early exhibition of the general respect that exists in humanity for what is great and powerful. Many of those boys have indeed become engine runners; others have risen slowly through the shops and in later life have attained the higher positions of master mechanics, in charge of many locomotives; some few have taken the royal road of technical education and, uniting with it a brief practical shop experience, have advanced with leaps and bounds past the merely so-called practical man to the influential superintendence of motive power while yet in the full vigor and energy of young manhood. It is the purpose of this writing to point out the means of success by the latter method, to mention some of the pleasures, duties and responsibilities of railway mechanical engineering, its study at the technical school, the personal qualifications needed, and the opportunities presented to the ambitious man in this comparatively new and unfilled branch of skilled engineering.

In this country the term "engineer" has been appropriated in mechanical lines by those who run a stationary or locomotive engine. Abroad the title Locomotive Engineer is reserved for those who design, build and superintend the management of locomotives. That reservation will perhaps obtain in America when technical graduates become more numerous in railway work. Railway Mechanical Engineering includes not only the

design, construction, operation and maintenance of locomotives, but also of cars, both freight and passenger. It covers the use not only of steam, but of electric traction and of electricity for lighting. In shop management modern methods of arrangement and equipment must be understood and practiced; electric, pneumatic and hydraulic appliances used, each as most suitable; and the economics of labor must be studied. The skilled purchase of railway material and the testing of existing equipment has to be supervised. European methods of locomotive engineering must be watched, and particularly is this true if one is engaged in contract shop manufacture of locomotives to compete in the world's markets of Japan, Australia, South America and elsewhere.

What are the pleasures of railway work? Chief of these is its variety. Man has ever been a creature fond of change. The traveler, passing from crowded London Cheapside to the grandeur of silence on Alpine glacier, from the æsthetic pleasures of the Louvre to view the squalid hordes of Islam at Mecca, is but the ancestral nomad—civilized. The same spirit that actuates him makes the railway mechanical engineer delight in his profession. First among his creations and care is a thing of power, not tied down to place, but roaming over the land from beside the sea, along green valleys, through deep gorges, or skirting lofty cliffs amid the wildest scenery. In the less important lines of his work he is called out upon this machine, not enough to be irksome, but to quicken his heart, freshen his lungs, and give zest to his spirits for more vigorous work in drafting room and office. The problems, too, that come up in design or management are almost infinite in number. He does not sit at a microscope and study the eyes of a beetle half a year, though that may be permitted to a few to be pleasure, but in superintending the design of a new locomotive his entire faculties must for a brief period be concentrated upon a judgment of one draftsman's detail and then upon another's work entirely different, and so on. The decisions to be made in the many lines of management; the choices from among the great variety of railway supplies; the necessity for his frequent presence and direction at different points along his road; the visits to car and locomotive works, steel works and foundries, or to the shops of other railroads, either in supervision of work being executed for him or in a general inspection visit to gain information and keep abreast with the best methods; the regu-

lar attendance at frequent Railway Club meetings and the annual Master Mechanics' Association convention,—all these preclude the remotest possibility of stagnation. To this is perhaps due the marked joviality of railway men. Incidental to the official position is also the free transportation for the man and his family—free over the whole road for the least important worker; free over neighboring railway systems and free in Pullman's for those a little higher; passes everywhere throughout the country for the Superintendent of Motive Power.

The work of the Locomotive Engineer if successful is sure of universal admiration, it is illustrated and praised in the railway technical press, discussed in the engineering associations, the designer congratulated by better known locomotive engineers whose long years of experience make their comment prized, the traveling public patronizes the road and remarks upon its improved equipment, all of which is indissolubly connected in the railway world with the engineer in charge.

Thus far the study of Locomotive Engineering has not received sufficient attention in the technical schools. There may be several reasons for this. Graduates have gone more largely into other lines. The schools in their management have been influenced by, even largely made up of, these graduates returned. Experimental laboratory engines, large and small, are with one notable exception exclusively of the stationary type and their behavior has been most minutely studied by stationary specialists. Students have naturally gravitated therefore into lines with which they were most familiar. They have not been familiar with the locomotive which is boiler plant, carriage and double engine combined to give a thousand horse-power within most contracted limits and to run under most adverse concomitants of instability, dust, weather, forcing and rough usage. Railroad motive power departments, with one exception, were not open to such men, while practical shop and road knowledge of locomotives seemed of more worth than theoretical ignorance. The steam engineering training of our technical schools has thus been almost altogether for the stationary engine, although the census of 1890 rated the horse power of our locomotives at ten million as against the four million developed in all the stationary steam power plants.

It is not at all difficult to obtain a professor of steam engineering who, a technical graduate, has risen to be in responsible charge of work. Many such successful teachers might be

mentioned. It is needless to say that a professor of Locomotive Engineering should have been a technical graduate with extended and official railway experience. As noted before, technical railroad men are few in the first place and the pleasures and rewards of railway engineering are so great that it has been rare that one has made the change to the quieter life of the university.

American locomotive practice has been preëminently commercial along the lines of the larger economies. In Europe economies are closer. Only recently the receiver of a prominent Western railroad told the writer that engineering is a science of getting the most cents of interest out of a dollar of investment. Engineering students get filled up with the theories of scientifically correct designing and management. This is proper if not to the exclusion of commercial common sense. Coal is not burned in a locomotive with eyes squinted on careful economy so as to get the most steam, and hence the most pulling power, out of a pound of coal. If the consumption can be increased from a ton to a ton and a half per hour, *i. e.* one-half more, and by so doing that locomotive can pull one-third more cars per train, the author of the improvement is a great engineer. The theoretical man would call it wasting coal, while the railroad business man would say that though the half more coal does not pull a half greater train, still the extra coal is almost the only cost of hauling the extra cars because no increase is made in the interest on locomotive, track and bonds, in the wages of that engine and train crew, or of the track and signal men, in salaries of officials, in taxes or insurance. Practical railroad men have made these large savings, and in the newness and vast expansion of American railroad business the general managers have not felt the need of the smaller economies, large though the aggregate might be, which the educated engineer alone could introduce.

In considering the place of Locomotive Engineering as a technical school study the question of time is at once confronted. The addition of a graduate year is the best solution. This additional year of careful preparation is worth so much towards the later rapid advancement. Some thoughts upon that arrangement will be followed by a consideration of what can be done in undergraduate time.

A course of lectures should be given, as briefly outlined in the catalogue of the University of Minnesota of date 1895-6. They are divided as follows:

Past and future development of the locomotive.

Materials of construction. Motive power specifications and standards.

Locomotive and train resistances. Ruling grade as affected by kinetic energy. The track from motive power point of view.

The locomotive boiler; types, proportions, details, grates and heating surfaces, lagging, smoke prevention, circulation, water, fuels, effect of temperature upon metals, testing, accessories and attachments, shop work.

The locomotive engine; details, piston speed, reciprocating parts, bearing surfaces, link and valve motions, steam distribution, heat insulation.

The locomotive as a carriage; limitations, frames, spring and equalizing rigging, running gear, journals, truck wheels, drivers and their counterbalancing, brakes, steam heat, cab.

The tender; tank and attachments, wood and iron frames, built up and solid trucks.

Locomotive management; engine loads, coal premiums, working crew systems, expert instruction, lubrication, performance sheets.

Compound locomotives; systems and types, requisites for economy, cost of building and repairs.

European locomotive engineering and conditions of competition with American locomotives.

The domain and outlook for electric traction. The involved problems from electrical, railway and business standpoints.

Drawing room practice; preparation, management and classification of work, preservation of records, relations with the shops.

The shops; their arrangement, tools, cost and subdivision of power, labor paying, apprentices, reduction of costs by specialized machinery, by replacing hand work with machine work, by standardizing and duplication of parts, and watchfulness for wastes.

The railway test room and test department; inspection and purchase of materials, service tests of equipment, relations with general store house.

The railway mechanical engineer and superintendent of motive power, their qualifications and duties.

Actual designing should be carried on along the following lines, carrying out the principles of the above lectures, but keeping always in sight the restrictions to theoretical design which railway experience has found financially and practically to exist:

Designing of locomotive parts by the best modern methods. Link and valve motion designing by the geometrical diagrams with practical modifications and working models. The indicator diagram and inertia in designing. Determination of drivers, cylinders, steam pressure, boiler and grate for a given power and service, for simple and compound locomotives.

The engineer is also to be trained along the special needs of railway service test department work and a suitable amount of the following should be included:

Testing of railway appliances and supplies, as safety valves, injectors, gauges, air pumps, brakes, springs, metals of construction, lubricants, fuels, feed waters and their purifiers. Locomotive testing in road service with and without dynamometer car; also on laboratory experimental plant to eliminate the variables and permit finer manipulation and closer inspection.

The work in car design should be short and cover a few of the leading types of freight cars and trucks, including couplers and air brake work. Passenger and sleeping car design is rather specialized work and to it not much time should be given.

The graduate year would be arranged as follows, the hours being credit hours per week, designing and testing requiring two hours work for each credit hour:

	1st Term.	2nd Term.	3rd Term.
Locomotive lectures..............	5	5	5
Locomotive designing...........	5	5	5
Testing..................................	3	1	3
Seminar work, railway journals, and thesis...............	2	2	5
Car lectures and designing....	2	4	0
Elective, subject to approval but preferably electrical engineering.....................	3	3	2
	20	20	20

In studying Locomotive Engineering during the undergraduate period something will be accomplished in the senior

year by using the time allotted to electives and to designing. The required subjects could also, if so decided, be very easily arranged with special reference to the needs of the prospective locomotive engineers. The course in valve gears might omit many types of high speed stationary design and then treat that most important part of the locomotive exhaustively. Thermodynamics would avoid all principles not related to locomotive practice; and windmills, gas engines and water motors would be omitted. Problems in design could be solely upon locomotives. The senior year in Locomotive Engineering would then be made to take a place similar to the senior year in electrical engineering at Cornell University.

Having taken Locomotive Engineering at the technical school the question arises as to the best way to enter the railway service. Locomotive shop work is unquestionably necessary. The summer vacations should be so spent if possible. Of course the best equipped man for an engineer is one who has had a general college education before his professional course. If two or three years can then be spent in a locomotive shop at nominal wages so as to be transferred frequently from one class of machines and work to another, the technical course to follow will be better improved. If the technical course precedes the railroad shop the latter will be better understood. On the Pennsylvania Railroad promotions can be made only from their own special shop apprentices who have been technical graduates. There are however very many railroads having no routine system of admission for technical graduates which are glad to get hold of one with shop experience even though it has not been gained in their own shops. A graduate therefore having had two or three years' shop practice will do well to get into the test department or drawing room of a first-class railroad. His abilities will soon make promotion for him because railroad officers are always on the watch to advance bright men into the upper places or to get them from another road.

A brief description of a railroad drawing room may not be amiss. The hours are short, seven or eight per day. The salary for the beginner about $60 a month. Two weeks' vacation in the year with no deduction of salary. Passes when desired. In railway work it is not customary to employ cheap help to make tracings for blue printing, the work being usually of such a

nature that the designer can more profitably make his own tracing from his incomplete drawing.

In a small office with six or eight draftsmen the chief draftsman or mechanical engineer usually deals directly with each subordinate; with fifteen or twenty draftsmen three or four are leading men, the chief directing often through them, all the designs finally coming to him for approval. To avoid errors a second draftsman checks up the work of the original designer and is held equally responsible with him for mistakes to an extent variable with the nature of the drawing. The chief draftsman then signs it as correct, and forwards it in case it is a drawing sufficiently extensive or standard as to require the approval of the superintendent. The shops are not permitted to make any changes from the drawings without the approval of the chief draftsman. Thus all work is correctly recorded in his office and for future designs his records only have to be consulted. Where a general drawing room is established on an old road, particularly where there has been a great variety in locomotive equipment, the correspondence and investigation before each standard can be adopted and changes made is exceedingly extensive.

Draftsmen are often sent out on the road for information and into the main shops or to the test department. There is thus opportunity to broaden one's knowledge and to get fully acquainted with the railroad's usages.

In handling a drawing room the methods of government should be different from shop rules. Draftsmen are a much higher class of workers and must be treated accordingly. The best work can be obtained when they are permitted as engineers to feel personally interested in their work and informed as to its success after leaving their hands. This may seem axiomatic, but the writer knows where that is not the custom and where draftsmen have been regarded as mere machines to turn out the thought of the superiors.

The routine work of a railway test department is in part the inspection of car wheels and axles before purchase, and the testing of flat and coiled springs, boiler steel and other material which is in constant and severe use. Special tests are often made when changing the place of purchase, especially when adopting new standards, as for piston rod packing, cylinder sight-feed lubricators, brake shoe material or journal bearings. Tests requiring greater engineering ability are made, as in re-

gard to the size and height of exhaust nozzles, smoke stack shape, grate area, driver counterbalance, valve action, injector efficiency or throttle and steam pipe area. Still more extensive are competitive trials between different classes of locomotives, covering coal and water consumption, with and without the dynamometer car, and involving the use of all the expert instruments of the testing engineer.

The variety of work of the Railway Mechanical Engineer has been mentioned. He must be the road's encyclopedia of mechanical information, knowing all that is best of other engineers' designs and how to apply them usefully and cheaply to his own road. He must cultivate cordial relations with officers of other roads, and this will naturally result in exchange of information, but be discreet in imparting such information to his competitor as shall not hurt his own road. The great army of railway supply men will often consume much of his time in urging him to favor their specialty, but he remembers that he cannot possibly be as well posted about injectors as the energetic man who is posted about nothing else, and so the engineer always learns something from the supply man and should listen to him patiently. In his periodical visits to the different division shops he should be on the lookout for improving methods of work, the need of modern or alteration and relocation of old machines, be quick to notice anything going wrong and take measures to have it corrected. Some cases in the writer's experience will illustrate: A connecting rod finisher was observed to be using too fine emery, requiring too long to work down the surface and putting on an unnecessarily fine polish. He acknowledged that he had asked for coarser emery, but it was not given him. That matter was corrected in a few days. A bolt heading machine was seen to be running much too slow for economical production; chilled car wheels, mounted on their axles, were unloaded with danger of cracking by dropping them off the end of the flat car; new cast iron eccentric straps were being bored out for passenger engines, though bronze straps had been made the standard. In this latter case the store-house was in fault for not properly filling the division master mechanic's order for bronze castings. In some shops and round-houses split cotters were absent from some of the connecting-rod keys, letting the keys be thrown out on the road when loose. A modern wet emery tool grinding machine was not being used to grind tools to the tabulated cutting and clearance angles

found by the manufacturers to be the best for quick and durable cutting.

Reference has been made to the charge of design in the drawing room and of the test department. The mechanical engineer is also the consulting engineer to his superintendent of motive power. If his road does not design its own locomotives he is asked his professional opinion and reasons as to what type is needed. If an engine does not make enough steam he has to be its doctor. If crank pins start to breaking he must show a draftsman how to calculate them to see if strong enough under proper usage. If the brakes of a coal car are not holding he must diagnose the difficulty. Compound locomotives come up and he is called upon to advise which of the twenty-five types is the best for the service of his road, and if need be design one perhaps in the early days when all compound locomotive designers had only stationary and marine practice as guide. All the railway technical papers are taken in his office and all glanced through and digested in part. He must keep up with the progress in steel manufacture, particularly of boiler, axle, tire and rod steels, as also the adaptation of steel and malleable iron castings and pressed steel in latest locomotive and car practice. Specifications for various materials are to be prepared and to be kept abreast with improvements. Acetylene gas for car lighting, roller curtain fixtures that the most stupid or irascible passenger cannot get out of order (and there are such fixtures), wrecking frogs that unfailingly replace a derailed car, air power for locomotive bell-ringers, the sand blast to prevent slipping of drivers, ribbed boiler tubes, stationary boiler design, chimney work, repair shop artillery for driving out refractory bolts, all of these hint at the varied details and responsibilities of this position. In all the designs and the standardizing the position of the general storehouse and their effect upon its stock carried and upon the interest accounts of the company must be born in mind. Electricity is recognized as a motive power and competitor to be absorbed, and on short lines where passenger traffic is fast and frequent, with light trains and the line to itself, it will probably be necessary in the near future to have plans ready for its adoption. The general consensus of expert electrical and railroad opinion is that for long distances or infrequent trains its possible adoption is very remote. The present efficient locomotive is capable of greater speed than the public is willing to pay

for, than the signal system could safely permit, or more profitable traffic make way for. The cost of installation is a commercial hindrance, and even if installed the low efficiency of intermittent and long distance operation, interest on investment of costly power stations and large conductors, would give no saving over the present steam traction.

Success in this profession implies learning, ability, untiring energy, alertness of thought and quick, independent decisions. It cannot be attained by the incompetent or by the use of chicanery or the artifices which in some pursuits are substituted for worth and work. Yet it lacks the charm of oratory, the dazzle of publicity, the swaying of opinions, which are so dear to the politician or the lawyer, and which surround them in their influence over men. Of all the branches of mechanical engineering, however, this one is the most abounding in life and activity. It is no place, this high tension of railway service, for the lover of quiet and moderate living. The speed of motion permeates the very air of offices, and the typical American as pictured abroad finds there his original.

I am led to close with some observations concerning the opportunities in railroad life. America is the distinctively railroad country of the world. In 1893 the world had 419,000 miles of railroad, of which 179,000 were in the United States and 148,000 in all Europe. A single American railroad has 3,400 locomotives, with 97,000 men on its pay rolls. It has been its policy for many years to take technical graduates into its shops, test department and drafting room, and from these "special apprentices" alone, to promote up through the various grades. Some of its best division superintendents of motive power are very young men, who have shown themselves worthy of rapid promotion. Another road, two years ago, appointed as superintendent of motive power a young man who from school went into the shops, was soon promoted, became a division master mechanic, where his tact in managing men, and his good judgment in caring for equipment while still keeping down expenses, brought him into notice, and he was called from this road to his present position. This road had previously done without technical men, but the policy of the management is now absolutely reversed. Only such men are now chosen for the various openings and trained for the future. A year ago one of their division master mechanics, who had seen several decades of service as a "practical" man, was replaced by a technical

graduate of successful experience on another road. Many other leading railroads are inaugurating the same system to get expert technical men into the motive power positions. The highest official of one of the largest lines in the Northwest told the writer recently, having been in conversation about a number of unsettled problems in locomotive engineering, that he was wanting to secure technical graduates, as they alone were fitted to handle such matters intelligently; that the average master mechanic who had risen through the shops and road service was entirely at sea in technical investigation; and that the scientific solution of some matters mentioned meant thousands of dollars on the monthly income sheet of his road. In conversation at the Railway Clubs and the American Railway Master Mechanics' Association the writer has heard the same sentiments reiterated. Railroads are to the mechanical graduate a vast field ready for harvest. The thousands of positions as shop foremen and master mechanics, round-house foremen, road foremen of engines, motive power engineers, division master mechanics and superintendents of motive power, engineers of tests, foremen of drawing rooms, chief draftsmen and mechanical engineers, general superintendents of motive power, chiefs of motive power,—these, in the immediate future, are to be filled by the technical graduate of today.

ORE DEPOSITS IN MINNESOTA.

BY ARTHUR H. ELFTMAN, M. S.

Minnesota, while largely an agricultural and lumbering state, has within her limits vast mineral deposits which, even in their early stages of development, have become an important factor of the state's resources. The only ores which have been developed to any extent are those of iron. Gold, silver, nickel, cobalt, copper, and manganese are known to exist in the various rock formations, but have not yet been developed.

It is intended to give only a very brief sketch of the present status of development of the above mentioned metals.

IRON.

The iron ores are found chiefly in the Vermilion and Mesabi iron ranges. On the former range they occur in the Keewatin or Lower Huronian formation. The only places where they are mined are Tower and Ely. Eastward from Ely, extending through the eastern part of Hunter's Island, are very favorable indications of immense bodies of ore which have not been explored to any great extent. The ore at Tower is hard hematite, quite free from phosphorous and sulphur. The Ely ore differs from the preceding only in the degree of hardness, it being a soft ore easily worked.

The ores of the Mesabi found in the Animike or Upper Huronian are: hematite on the western end; magnetite in the central and eastern Mesabi. Several attempts have been made to mine the magnetite, but pure ore has not yet been found in quantities large enough to cover the expenses of mining. The magnetite-bearing rock occurs in large quantities, but ore rich in iron is quite limited.

The workable ores are the hematite deposits of the western Mesabi. The ore here occurs in large irregular bodies of soft hematite, easily worked and accessible without difficulty. Like the Vermilion ore it is found at the surface, usually concealed by a slight covering of glacial drift.

Development and exploration have not gone far enough to show the entire extent of the ore bodies thus far discovered. It cannot be said that all of the existing ore bodies have been discovered. The relative quantity of ore on the Mesabi and Vermilion ranges cannot be computed, owing to incomplete explorations on both ranges.

Titaniferous magnetite is found in the Keweenawan gabbro overlying the Animike of the Mesabi. This magnetite is generally a lean ore and does not occur in such large quantities as are usually reported. Even if processes were known by which the metal could be profitably extracted from titaniferous ore, this part of the mining industry of the state would be an insignificant factor.

MANGANESE.

Manganese has been found in workable quantities on the Mesabi range associated with the hematite. Analyses of iron ores from other localities show traces or a low percentage of manganese.

GOLD AND SILVER.

During the last thirty years discoveries of gold and silver have been announced from every part of the state. Every county at some time seems to have had its gold excitement, whether based upon the unearthing of a brass kettle or the finding of a speck of gold in a mountain of granite. Gold occurs in small quantities in the oldest rock formations. It is still very doubtful whether deposits rich enough to pay for extracting the gold will ever be found within the limits of the state.

NICKEL AND COBALT.

Nickel and cobalt have been found only in very small quantities in bog manganese ores, pyrrhotite from the Animike, and the ferro-magnesian silicates of the Keweenawan basal gabbro. The most reliable analyses show that nickel runs as high as three per cent. and cobalt 0.71 per cent. Usually analyses show but a trace or less than one per cent. of the two combined. The two metals are associated with each other. The nickel, however, predominates.

Up to the present time nickel ore has not been found in quantities warranting an outlay for mining development. Since the nickel has been found in small quantities scattered throughout the great gabbro mass of northeastern Minnesota it is possible that it may be found in paying quantities in localities where the

basic constituents of the gabbro have been collected by the differentiation of the original magma and a further concentration of the nickel effected through the decomposition of these segregated basic masses.

COPPER.

Copper is found in the Keweenawan rocks of the lake Superior region. Although this formation covers an extensive area in Minnesota the copper-bearing horizon is limited and carries but very little copper. Chalcopyrite is scattered throughout the basal gabbro in small quantities. Malachite is found as incrustations upon the rock. Native copper occurs in the amygdaloidal lava flows which largely compose the copper-bearing horizon. The copper fills the cavities of the vesicular layers of rock and is also found in veins.

Numerous specimens of float copper have been found in the glacial drift throughout the state, but these were presumably derived from the Keweenawan rocks. From the character of the rock and other mineralogical associations it is not expected that copper will ever be found in paying quantities. At present this is confirmed by explorations at numerous places along the north shore of lake Superior. Very little copper was found at Cascade River and the Stewart river "mines." These two localities the writer considers show the most favorable indications in the state.

FOUNDATIONS FOR A POWER HOUSE.

BY GEORGE J. LOY, B. C. E., '84.

In the recent construction of the foundation of a power-house for the new water-works system of Spokane, Wash., a number of unexpected difficulties, which necessitated certain changes in the proposed plans, were met with. These difficulties and their remedies will be briefly described.

The plans for the power-house were prepared by the Consulting Engineers of the water-works system, and then submitted for approval to the well known Hydraulic Engineer, J. T. Fanning, of Minneapolis. The power-house was to be located on the river bank about 40 feet from low water mark; the subsoil consisted of a bed of gravel known to be of considerable depth. The gravel occurred in layers of different thicknesses, consisting of coarse sand alternating with coarse gravel and small boulders.

According to the plans the masonry was to be of granite, laid on concrete footing, three feet thick. The depth of the excavation for the river wall was to extend ten feet below low water mark, to allow a discharge under water from the five water wheels (each fifty-four inches in diameter), and also of the concrete footing. When excavating was first started, three centrifugal pumps, with a combined capacity of 22,000 gal. per minute, were put in operation. The size of the excavation was 120x40 feet. After working a short time with these pumps it was found that the best they could do was to lower the water two feet below the water level of the river. When this became apparent the excavation was divided into smaller areas, but still the pumps failed to fulfill the requirements. This state of things lasted for ten days, when a rise in the river necessitated an abandonment of all work.

The plans were now entirely changed, a grillage foundation on piles being substituted for the masonry and concrete. This foundation was to consist of piles, driven in rows, two feet eight inches apart, the rows being three feet apart. On top

of the piles was placed ordinary grillage, consisting of timbers fourteen inches square, which in turn was covered with a solid flooring of timber twelve inches square, which was to support the wall.

The excavation was finally completed by finishing small portions at a time and driving sheet piling around the sides and carefully filling up all leaks. The sheet piling was driven to a depth of about ten feet so that it would stand after the excavation was finished. It was found by experiment that the best sheet piling in this case was made of small piles about ten inches in diameter. Other kinds, such as grooved lumber piling and piling of square timbers, crushed before it could be driven to the required depth. Even with this method the final work of excavating had to be done in three feet of water.

The bearing piles for the wall and piers were driven from eleven to sixteen feet below the point of cut-off. Each pile will have a load of seven tons, with a factor of safety of at least two. The bearing piles had to be cut off by hand under water with an ordinary cross-cut saw, which, however, was fastened in a frame somewhat resembling that of a buck-saw, but having the middle brace raised three feet above the saw blade. The piles were first all cut off at a point out of water just three feet above the required point, and were afterwards cut off at the required point, the saw being held in its true position under water by means of the brace, which slid across the top of the pile out of water. Four men were required to run the saw. Cap timbers were next drift-bolted to the piles. Owing to their buoyancy eight men were required to hold them down while they were being drift-bolted. To facilitate drift-bolting a follower, composed of a piece of gas pipe and a round iron bar, was used. The 12-inch timber floor was next drift-bolted to the caps in a similar manner.

It was now thought advisable to bring the flooring up to the surface of low-water mark, which was done. This would enable the masonry to be laid out of water with more care.

At this juncture another change in the plans was made; this was due to the desire on the part of the city officials to rush the construction work. A concrete wall was substituted for the proposed masonry wall, the dimensions of the larger wall being 120 feet long by 30 feet high with an average thickness of 7 feet. The construction of this wall took ten days, this being about one third the time necessary to construct a similar

masonry wall. During one day of nine hours this wall was built up six feet. The composition of the concrete was as follows: Portland cement, 1 part; sand, 2 parts; gravel, 1 part; broken stone, 3 parts.

A wooden frame-work for holding the concrete in place until set, was constructed as follows: 6″ x 8″ posts, spaced eight feet apart, were set up on either side of the wall. Each pair of these posts was tied together every seven feet in height by ¾″ circular iron rods. A wall inside of these posts was now constructed by laying up 2″ x 12″ planks surfaced on the inside. The wall was braced on the outside by light braces to prevent bending. Light mouldings were placed on the inside of these walls, so as to form joints on the concrete, thus giving it the appearance of masonry. These mouldings were ⅜″ x ⅞″, three being used for each joint; two were laid flat, and the third edgewise between them, thus giving the joint an appearance of having a chisel draft on either side. Arch stones were shown in like manner. The inner surfaces of these walls were coated with soap-suds to prevent the concrete from sticking to the wood. Openings, anchor-bolts, etc., are easily placed in such a wall.

In laying the concrete, special care was taken that the material which was placed next the mouldings should contain no coarse gravel or rocks. This of course gives a smooth and neat appearance to the surface and joints. After this wall was completed it was carefully watched for a month, but no settling or cracks could be detected.

The principal changes in the plans, that of substituting grillage for concrete footings and a concrete for a masonry wall, gain several advantages; first, it reduced the depth of excavation ten inches and avoided the necessity of laying concrete or masonry under water; second, it allowed of a change in the 72″ circular draft tube, to a smaller oval one; third, it saved at least fifteen days in the time of construction of the work. This last was an important item, inasmuch as the rainy season, bringing with it high water, was close at hand.

DESCRIPTIVE GEOMETRY AND WORKING DRAWINGS.

BY PROFESSOR W. H. KIRCHNER.

For technical purposes, it is of the utmost importance to represent solids and other figures in three dimensions by a drawing in one plane. A variety of methods have been introduced for this purpose. All, however, are systems of projection.

Descriptive (practical solid, darstellende) geometry, is the theory of making projections of any accurately defined figure, such that from them can be deduced the figure itself and all its metrical properties.

Under the name of "Geometrie Descriptive" Monge (1746-1818) about 1794 invented a method of drawing in plan and elevation or orthographic projection.

Plans and elevations, especially of buildings, were in use before his time, and rules had been developed to determine by construction from drawings the shape of stones in vaults and arches. These rules were reduced to a consistent method of projection by Monge.

Thus descriptive geometry dates from Monge, whose treatise appeared in 1800.

Since then purely geometrical methods have been continuously extended, especially by Poncelet, Steiner, Chasles, Von Staudt and Cremona. The beginnings of perspective date from the time of the Greek mathematicians; at present it is generally treated as a special case of projection. The theory of geometry in general, treated by the means of projection, is now considered as descriptive geometry.

Descriptive geometry was first taught at West Point, in 1817, but did not find its way into other institutions for a number of years. Today it is considered an important element and is found in the curriculum of all schools of engineering.

A working drawing is simply the application of practical geometry to the representation of any object and conveys to the mind of a skilled workman clear and exact information of

form and magnitude. Drawing has become such an important factor in constructive engineering that it is well described as "the language of the work-shop." The use of working drawings in engineering has become so general and so extensive that all persons engaged in manufacturing industries are expected to understand a projection drawing, whether contractors, users, buyers or sellers of machinery.

This continued and ever increasing use of projection in the works and the office of the commercial engineer has demonstrated that for practical purposes it is expedient to make some changes in the nomenclature and the preliminary notions of descriptive geometry, such as the names of the projections or views, and the relative position of the object and the planes of reference.

The *rabatting* of the planes and consequently the arrangement of the views on the drawing depend upon this preliminary relation.

Descriptive geometry is a science when it shows a mathematical basis for its methods, and an art when it deals with the execution of its methods, hence any change we make in its preliminary notions of arrangement, execution and nomenclature, will not necessitate any change in its mathematical demonstrations.

Practical experience in making working drawings has shown that a few changes in this direction are for the better. The subject is taught more and more with reference to its practical application, and is pursued mainly by students who expect to follow some of the engineering professions as a livelihood.

In passing from his text book to the practical problem the student experiences some trouble in becoming familiar with the new arrangement of the projections. The difficulty is not great, but there is no occasion for its existence, and it should be removed.

It may be said that this is merely passing from the first to the third quadrant in descriptive geometry, and that no difficulty should arise in the transition. However, such is not the case, and the record of the class room shows that the average student cannot in the limited time work with equal facility in all four quadrants, and manipulate a problem involving more than one quadrant with ease. Nor is it advisable to devote a considerable portion of his time to acquire facility in passing

from one quadrant to another at the expense of his knowledge of principles and methods.

In practice he will have no occassion to pass from one arrangement of views to another, and whatever facility he may have acquired in that direction is discipline gained at the expense of practical knowledge.

The time saved by avoiding unnecessary transformations is used in extending the scope of the subject matter, and nothing is lost in the disciplining of the geometric imagination, in fact there is a decided gain. All English and Continental descriptive geometries use the first quadrant. The first chapters generally contain problems illustrating the projections for points and lines placed in all four quadrants, but the larger part of the treatise confines the problem to the first quadrant.

Nearly all American texts treat the subject in the same manner, not even excepting those published within the last ten years. In works on mechanical drawing we find that many of the books written within the last decade have adopted the shop method of plan above the elevation, and a few have discarded the terms plan and elevation and used top view, front view and the like.

The line of intersection of the horizontal and vertical planes of reference is called both the ground line and the axis. As an illustration of the different notations we find the following: For this line of intersection, GL, G, XY, X, AB, etc. For the horizontal and vertical projection of a point (A) we find, $a^h a^v$, aa', A_1A_2, $a^T a^F$, $a'a''$, and others. For lines, traces and planes we find the same diversity, and in addition the use of heavy and light lines, broken and dotted lines, dash and dot lines. In passing from one text to another we are quite often compelled to study the notation. Fortunately, all of this notation and the ground line or axis do not appear in the practical problem and no difficulty arises.

Foreign drafstmen use the first quadrant method of arrangement of views. The third quadrant is used in American practice. Many teachers prefer to dispense with the question of quadrants, and obtain the projection by assuming the object to be placed within a transparent cube, the projections being called the top view, front view, right view, and so on. The unfolding or *rabatting* of the faces of the cube brings the views in their proper relation. This avoids the old method of having the right view or elevation on the left side of the front elevation.

The third quadrant or shop method is generally followed in our manual training and mechanic arts high schools, where the study of projection is pursued without taking up the more complicated and general constructions of descriptive geometry. In colleges of engineering the practical or shop method is used in the drawing room, but not nearly as much as one would expect.

Treatises on machine drawing and design and kindred subjects, if English, are illustrated chiefly by first quadrant methods, if American we find that nearly all of the new illustrations of details of engineering practice are drawings in the third quadrant and in some occasionally an old cut introduced showing the first quadrant method. If simple details are shown no difficulty is experienced, but when we have right views in addition to the front, it is annoying to say the least.

The use of photography in making illustrations has done much to bring the drawings of the practical draftsman into engineering periodicals. It is to be hoped that it will not be long before we can say there is no essential difference between the method of the recitation room and the office of the engineer.

SOCIETY OF ENGINEERS

IN THE

UNIVERSITY OF MINNESOTA

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Frank H. Constant, C. E.
H. Wade Hibbard, M. E.
C. H. Kendall, C. E.
H. E. Smith, M. E.
W. H. Kirchner, B. S.
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Garvey, J. J.
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Irwin, J. B.
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Lee, E. A.
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Magnusson, C. E.
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Neil, V. A.
Pratt, G. A.
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Silliman, H. D.
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Taylor, E. W. D.
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Wales, R. T.
Walker, F. B.
Wheeler, H. M.
Woodford, G. B.
Wright, R. V.
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CORRESPONDING MEMBERS.

1875.

NAME AND RESIDENCE.	DEGREE.	OCCUPATION.
LEONARD, HENRY C. (B. S., '78) Minneapolis, Minn.	B. C. E.	Physician.
RANK, SAMUEL A. . . . . Central City, Colo.	B. C. E.	Civil and Mining Engineer.
STEWART, J. CLARK . . . . Minneapolis, Minn.	B. C. E.	Physician: Prof. of Pathology at University of Minnesota.

1876.

GILLETTE, LEWIS S. . . . Minneapolis, Minn.	B. C. E.	President of the Gillette-Herzog Manufacturing Co.
HENDRICKSON, EUGENE A. . St. Paul, Minn.	B. C. E.	Lawyer.
THAYER, CHARLES E. . . Minneapolis, Minn.	B. C. E.	Grain Dealer.

1877.

PARDEE, WALTER S. . . . Minneapolis, Minn.	B. Arch.	Architect.

1878.

BUSHNELL, CHARLES S. . . Minneapolis, Minn.	B. M. E.	Mf'r. Stoves, Ranges and Furnaces.

1879.

DAWLEY, WILLIAM S. . . Chicago, Ill.	B. C. E.	Chief Engineer C. & E. I. Railway Company.
*FURBER, PIERCE P. . . .	B. C. E.	Died April 6, 1893.

1883.

BARR, JOHN H. . . . . . Ithaca, N. Y.	B. M. E.	Ass't Prof. Mechanical Engineering, Cornell University.
PETERS, WILLIAM G. . . . Tacoma, Wash.	B. C. E.	Vice-President Columbia National Bank.
SMITH, LOUIS O. . . . . Le Sueur, Minn.	B. C. E.	Civil Engineer.

1884.

LOY, GEORGE J. . . . . . Spokane, Wash.	B. C. E.	Civil Engineer.
MATTHEWS, IRVING W. . . Waterville, Wash.	B. C. E.	Real Estate, Insurance and Abstracts of Titles and Civil Engineer.

1885.

BUSHNELL, ELBERT E. . . New York City.	B. M. E.	Proprietor of the Hooper Typewriter Prisms.
*FITZGERALD, PATRICK T. .	B. C. E.	Died, April 2, 1887.
REED, ALBERT I. . . . . Hastings, Minn.	B. C. E.	Civil Engineer.

1886.

NAME AND RESIDENCE.	DEGREE.	OCCUPATION.
WOODMANSEE, CHARLES C. Midway Park, St. Paul.	B. ARCH.	Book-keeper.
1887.		
ANDREWS, GEORGE C. Minneapolis, Minn.	B. M. E.	Heating Manufacturer and Contractor.
CRANE, FREMONT (B. S. '86) Prescott, Arizona.	B. C. E.	Civil Engineer.
1888.		
ANDERSON, CHRISTIAN Portland, Ore.	B. C. E.	Civil Engineer.
LOE, ERIC H. Minneapolis, Minn.	B. M. E.	Mechanical Engineer, with Nordyke & Marman.
MORRIS, JOHN West Pullman, Ill.	B. M. E.	Assistant Superintendent and Mechanical Engineer of Plano Manufacturing Co.
HOAG, WILLIAM R. (B. C. E. '84) Minneapolis, Minn.	C. E.	Prof. of Civil Engineering, University of Minnesota.
1889.		
COE, CLARENCE S. Wenatschee, Wash.	B. C. E.	Civil Eng. in Engineering Dept. of C., M. & St. P. Ry. Co.
1890.		
BURT, JOHN L. Minneapolis, Minn.	B. C. E.	Commission Merchant.
DANN, WILBER W. Minneapolis, Minn.	B. C. E.	Civil Eng., Supt. of Water Works Con'st'n at St. James, Minn.
GILMAN, FRED. H. Minneapolis, Minn.	B. C. E.	Editor Mississippi Lumberman.
GREENWOOD, WILLISTON Minneapolis, Minn.	B. C. E.	Civil Engineer.
HAYDEN, JOHN F. Minneapolis, Minn.	B. C. E.	Newspaper work.
HIGGINS, JOHN T. St. Paul, Minn.	B. C. E.	Physician.
HOYT, WILLIAM H. Duluth, Minn.	B. C. E.	Assistant Engineer, Duluth & Iron Range R. R.
NILSON, THORWALD E. Minneapolis, Minn.	B. M. E.	Manager of the Norgren Distilling Co.
SMITH, WILLIAM C. St. Paul, Minn.	B. C. E.	Assistant Engineer, N. P. R. R.
WOODWARD, HERBERT M. Boston, Mass.	B. M. E.	Instructor of Wood Working, Mechanic Arts High School.
1891.		
ASLAKSON, BAXTER M. Dayton, Ohio.	B. M. E.	With the Stillwell-Bierce & Smith-Vaile Co.
CARROLL, JAMES E. Minneapolis, Minn.	B. C. E.	City Engineer's Office.

NAME AND RESIDENCE.	DEGREE.	OCCUPATION.
CHOWEN, WALTER A. . . . St. Croix Falls, Wis.	B. C. E.	On Survey of Minneapolis, St. Paul & Ashland R. R.
DOUGLAS, FRED L. . . . New York City.	B. C. E.	Civil Engineer.
GERRY, MARTIN H., Jr. (B.M.E.'90) Chicago, Ill.	B. E. E.	Superintendent of Motive Power of the Metropolitan West Side Elevated Railroad Co.
HUHN, GEORGE P. . . . Minneapolis, Minn.	B. E. E.	Flour City National Bank.
	1892.	
BURCH, EDWARD P. . . . Minneapolis, Minn.	B. E. E.	Electrical Engineer, Twin City Rapid Transit Company.
BURTIS, WILLIAM H. . . Minneapolis, Minn.	B. E. E.	Electrical Engineer and Contractor.
FELTON, RALPH P. . . . Minneapolis, Minn.	B. M. E.	Fire Insurance.
GOODKIND, LEO. . . . St. Paul, Minn.	B. ARCH.	City Supt. of Schoolhouse Construction.
GRAY, WILLIAM I. . . . Minneapolis, Minn.	B. E. E.	Electrical Engineer and Contractor.
HANKENSON, JOHN J. . . Minneapolis, Minn.	B. C. E.	Bridge and Sanitary Engineer.
HIGGINS, ELVIN L. . . . Hutchinson, Minn.	B. C. E.	Teacher.
HOWARD MONROE S. . . Minneapolis, Minn.	B. E. E.	Electrical Engineer and Contractor.
MANN, FRED M. . . . Philadelphia, Pa.	B. C. E.	Instructor Architectural Design, U. of Penn.
PLOWMAN, GEORGE T. . . Minneapolis, Minn.	B. ARCH.	Draughtsman.
	1893.	
ANDERSON, OLE J. . . . Nicollet, Minn.	B. C. E.	Nicollet County Surveyor.
AVERY, HENRY B. . . . Minneapolis, Minn.	B. M. E.	With Gillette-Herzog Manufacturing Co.
BATCHELDER, FRANK L. . . St. Paul, Minn.	B. C. E.	With C. F. Loweth.
CHASE, ARTHUR W. . . . Hastings, Minn.	B. E. E.	Electrician.
COUPER, GEO. B. . . . Northfield, Minn.	B. M. E.	Manager Northfield Electric Light Company.
DEWEY, WILLIAM H. . . New York City.	B. E. E.	Assistant Engineer for the American Boiler Co.
ERF, JOHN W. . . . . Minneapolis, Minn.	B. C. E.	With Gillette-Herzog Mfg. Co.
GUTHRIE, JOHN D. . . . Minneapolis, Minn.	B. E. E.	Medical Student, University of Minnesota.
HOYT, HIRAM P. . . . Minneapolis, Minn.	B. C. E.	With Gillette-Herzog Mfg. Co.

NAME AND RESIDENCE.	DEGREE.	OCCUPATION.
MORSE, GEORGE H. . . . Minneapolis, Minn.	B. E. E.	Instructor in National School of Electricity.
REIDHEAD, FRANK E. . . Minneapolis, Minn.	B. E. E.	Electrician, Minneapolis General Electric Co.
SPRINGER, FRANK W. . . Minneapolis, Minn.	B. E. E.	Scholar in Electrical Engineering.
WASHBURN, DELOS C. . . Minneapolis, Minn.	B. ARCH.	With J. T. Fanning.

1894.

BRAY, GEO. E. . . . . . Virginia City, Minn.	B. M. E.	Electrical Superintendent of Mining Company.
CHALMERS, CHARLES H. . . Minneapolis, Minn.	B. E. E.	Electrician and Assistant Manager, D. & D. Electric Mfg. Co.
CUNNINGHAM, ANDREW O. . New Orleans, La.	B. E. E.	With Gillette-Herzog Mfg. Co.
GILL, J. H. (B. M. E., '92) . . Minneapolis, Minn.	M. E.	Instructor in Shop Work, University of Minnesota.
GILMAN, JAS. B. . . . . Minneapolis, Minn.	B. C. E.	With Gillette-Herzog Mfg. Co.
JOHNSON, NOAH. . . . St. Paul, Minn.	B. C. E.	General Office G. W. R. R.
TRASK, BIRNEY E. (B. C. E., '90) Highland Park, Ill.	C. E.	Professor of Mathematics, Northwestern Military Academy.
WEEKS, WILLIAM C. . .	B. C. E.	Venezuela Survey.

1895.

ADAMS, GEO. F. . . . . Minneapolis, Minn.	B. E. E.	Electrical Engineering Co.
BISHMAN, A. E. . . . . Willmar, Minn.	B. E. E.	Supt. Electric Light Plant.
BOHLAND, JOHN A. . . . St. Paul, Minn.	B. C. E.	Draughtsman, Bridge Dept. G. N. R. R.
CASSEDY, GEO. E. . . . St. Paul, Minn.	B. C. E.	Draughtsman, Bridge Dept. G. N. R. R.
CHAPMAN, L. H. . . . St. Paul, Minn.	B. C. E.	Engineering Dept. G. N. R. R.
CUTLER, HARRY C. (B. E. M. '94) Camp Golden, Whitehall, Mont.	E. M.	Assayer, A. D. & M. Co.
CHRISTIANSON, PETER. (B. E. M. '94) Minneapolis, Minn.	E. M	Instructor in Mining at University of Minnesota.
EDDY, HORACE T. . . . Minneapolis, Minn.	B. E. E.	Graduate Student, University of Minnesota.
ROUNDS, FRED M. . . . Minneapolis, Minn.	B. E. E.	Electrician, with Standard Telephone & Electric Co.
SHEPHERD, B. P. . . . Minneapolis, Minn.	B. M. E.	Draughtsman, with Paul & Hawley.
TANNER, H. L. . . . . Minneapolis, Minn.	B. E. E.	Electrician, with Burtis & Howard.

NAME AND RESIDENCE.	DEGREE.	OCCUPATION.
TILDERQUIST, WM. . . . . Vasa, Minn.	B. M. E.	
VON SCHLEGELL, F. . . .	B. E. E.	With St. Anthony Water Power Company
WEAVER, A. C. . . . . . Minneapolis, Minn.	B. M. E.	Draughtsman.
WILKINSON, CHAS. DEAN, . Gibbonsville, Idaho.	B. E. M.	In Chlorination Plant, A. D. & M. Co.